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DOT HS-805 303

DEVELOPMENT AND EVALUATION OF A BELT RESTRAINT SYSTEM FOR SMALL CARS USING FORCE LIMITING

Michael J. Walsh
Barbara J. Kelleher

Calspan Corporation
4455 Genesee Street
Buffalo, New York 14225

Contract No. DOT HS-7-01679
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April 1979
FINAL REPORT

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16. Abstract

Development and evaluation of a force limited belt restraint system for small cars has been completed at Calspan Corporation. The belt restraint system with passive capability was developed through the use of three dimensional computer simulations and sled tests. The system has demonstrated performance evaluation criteria values less than or equal to FMVSS 208 limits for the 50th percentile ATD right front passenger at 72 Km/hr (45 MPH) in sled tests using a Chrysler L-body and at 56 Km/hr (35 MPH) for the 50th percentile ATD driver. The effects of belt pretensioning were investigated along with special consideration of the problem of properly restraining the 6 year old size.

This development was conducted under U.S. Department of Transportation, National Highway Traffic Safety Administration Contract No. DOT-HS-7-01679.

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METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

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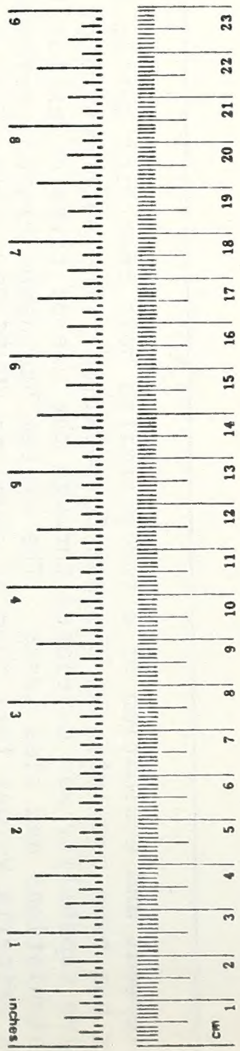
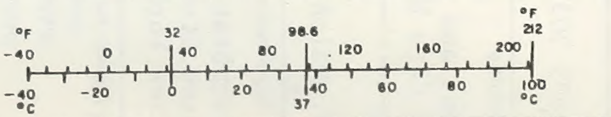


Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



FOREWORD

This report presents the results of a program entitled "Development and Evaluation of a Belt Restraint System for Small Cars Using Force Limiting". This study was performed by Calspan Corporation's Advanced Technology Center for the National Highway Traffic Safety Administration (NHTSA) under Contract No. DOT-HS-7-01679. Dr. Carl C. Clark was the Contract Technical Manager.

The objectives of this developmental and evaluation program were (1) to develop a belt restraint system that included a capability for passivity using force limiting to control the belt loads generated in crash simulations, (2) to investigate the effects of pre-tensioning of the belt system, (3) to compare the results of three-dimensional computer simulations of the occupant with the results of sled test crash simulations, and (4) to evaluate the system for performance with regard to FMVSS 208 injury criteria values for the six year old, 5th percentile female, 50th percentile male and 95th percentile male sized Anthropometric Test Devices (ATDs) when exposed to sled test crash simulations in a small car (Chrysler L-body) at velocities (BEV) in excess of 48 Km/hr (30 mph).

In addition to the four main objectives stated above the restraint system developed was to have a capability to demonstrate use under load and be producible within the state of the art of current manufacturing processes.

A secondary aspect of this program was to compare, in a short series of sled tests, the affect upon a 50th percentile anthropometric test device (ATD) of pre-inflated energy distributing modules in lateral crash simulations as opposed to no energy distribution in the same type of crash.

The authors acknowledge the many helpful suggestions and comments of Dr. Clark during the course of this program, particularly with regard to side impact studies with the pre-inflated energy distributing modules and methods of storing computer simulation data for future access.

The opinions and findings expressed in this report are those of the authors and not necessarily those of the National Highway Traffic Safety Administration.

This report has been reviewed and is approved by:

K. Hendershot

Kenneth C. Hendershot, Head
Transportation Research Department

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1.0 INTRODUCTION

All automobiles currently manufactured or marketed in the United States are equipped with occupant restraint systems. These restraint systems are either "active" or "passive". The active systems consist of lap and shoulder belts for the outboard front seat occupants. These systems are termed active because they require overt action on the part of the person to buckle the belt across his or her lap and torso. Failure of a considerable percentage of the driving population to use this restraint system has prompted an interest in the development of passive belt restraint systems which would protect the occupant during a collision. A system is termed passive* when no overt action is required by the occupant to engage the system.

Passivity is not a necessary condition for a high percentage usage rate but it has been generally assumed to be a sufficient one. Other considerations must be taken into account when evaluating the sufficiency of passivity toward raising the use level of a restraint system. In any belt restraint system there is an inherent requirement for the person to be able to disengage the belt after a crash. Unfortunately, if the belt and mechanisms for deployment and use are cumbersome and/or uncomfortable to the user, the system will be disengaged prior to the crash, thereby being no more effective than the unused active system.

The National Highway Traffic Safety Administration (NHTSA) has defined an automotive crash safety program wherein passive occupant protection goals in frontal impacts are being extended first to higher speed and more recently to greater emphasis on small cars. Traditionally when one thinks of passive restraint systems one thinks of Air Cushion Restraint Systems (ACRS) commonly called "air bags". ACRS and standard webbing passive belt restraint systems have been demonstrated to be effective occupant protection devices in car crashes at 48 Km/hr (30 MPH) in both large and small cars. Research and development toward the higher speeds, 64 Km/hr (40 MPH), and smaller vehicle occupant protection capability of the ACRS continues to be funded by the NHTSA. However, at this increased energy level a belt system comprised of standard

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*Presently referred to as "automatic".

webbing (nylon or polyester) would impart loads to the upper torso that could be injury-producing. Herein lies the rationale behind this reported development work.

The objectives of this program were multi-faceted. They were: (1) to develop a producible belt restraint system that in addition to limiting the upper torso load applied to an anthropometric test device (ATD) would include: a capability for passivity, a capability for determining use of the belt under load after the crash, produce performance evaluation criteria data less than or equal to the limits prescribed in FMVSS 208 at speeds of 64 Km/hr (40 MPH) or higher in a small car (Chrysler L-body) during frontal impact sled testing; (2) to investigate the effects of pretensioning of the belt system; (3) to compare the results of three dimensional computer simulations of the occupant with the results of sled tests; and (4) to compare the effect of pre-inflated energy distributing modules with no energy distribution in lateral sled tests.

In order to develop and evaluate this system Calspan Corporation performed 40 sled test crash simulations on the 12 inch HYGE sled facility and 28 three dimensional computer simulations utilizing the Calspan-developed CVS III digital computer program at the Edgewood arsenal facility. The input parameters and the output data are stored at the Edgewood facility for rapid access by interested investigators.

The composition of the program was influenced primarily by the desire to develop and evaluate a force-limited belt system for occupant protection at collision speeds (BEV) above 64 Km/hr (40 MPH) using a range of ATD sizes from the 6 year old to the 95th percentile male. It was anticipated that the use of the CVS III computer program could be utilized as an aid in the design and development of the system. However, it became apparent early in the program that while the 50th percentile ATD model was sufficient for simulating the responses of the 50th percentile ATD, the models for other sizes (6 year old, 5th percentile female and 95th percentile male) were not representative of ATDs in their respective sizes. A reasonable computer simulation of the

responses of these off-size ATDs could not be accomplished within the scope of this program.

With regard to protection of the 6 year old-sized ATD it was determined through sled tests that not only is the 6 year old size occupant not protected by a 'torso belt only' restraint system, but, in addition, this size occupant demonstrates a requirement for special considerations in restraint system design. FMVSS 208 performance evaluation criteria were exceeded even with the use of an active lap belt in the tests performed. Further, movement of the upper anchor point location, to present a more suitable deployment of the torso belt, did not enhance the protection of the system. Investigation toward a solution to this problem is the subject of additional work being funded under the optional Task 7 clause of the contract and will be reported in a separate publication.

The sections which follow first present a description of the restraint system developed under this program. Section 2.0 reviews the restraint system development while Section 3.0 presents the developmental computer simulations. Section 4.0 describes the restraint system testing and evaluation with regard to both sled testing and computer simulations. The results obtained from Section 4.0, System Testing and Evaluation, are discussed in Section 5.0. Conclusions and recommendations are covered in Section 6.0 and relevant reference material is presented in Section 7.0.

During the course of this program, all of the data from the experimental sled runs have been presented in monthly progress reports. For the sake of completeness, the experimental data is included along with on-line polaroid sequence camera photographs in Appendix A. Appendix B presents selected computer plots obtained from the CVS III simulations with overlay, where applicable, of the comparable sled test data from the conditions simulated. Appendix C contains a bibliography of reports on related subjects.

2.0 RESTRAINT SYSTEM DEFINITION

This section describes the considerations evaluated in the evolvement of the force limited belt restraint system for small cars. Because of the limited resources available and the desire to develop a system that would have at least a "near production" capability, only currently producible components were considered.

- Vehicle Determination

The first step in the development of any restraint system is the determination of a representative vehicle. For this work a Chrysler Corporation L-body (Omni-Horizon) was chosen based upon information supplied to the NHTSA that it was Chrysler's intent to maintain production of this basic interior for at least a five year period. Chrysler agreed to sell an L-body (body-in-white) to Calspan Corporation for the purpose of building a body buck for sled testing. Chrysler also supplied a 48 Km/hr (30 MPH) barrier crash pulse from an L-body crash test.

Having determined the vehicle and, through the crash deceleration pulse, the crash environment (crash environment in this context only means the deceleration severity in the longitudinal direction and does not take into account such parameters as vehicle pitch, intrusion, etc.) performance evaluation criteria limits were determined.

- Performance Evaluation Criteria Goals

As stated earlier, one of the objectives of this program was to develop a belt restraint system for small cars that would produce performance evaluation criteria (PEC) levels that are less than or equal to those upper limits stated in FMVSS 208 at a velocity change of 64 Km/h (40 MPH) or greater. In an effort to minimize the number of sled tests required to develop and evaluate the system it was decided that the 50th percentile male anthropometric test device (ATD)

would be the primary surrogate used and that the PEC goals for this ATD would be 75 percent of the FMVSS 208 PEC limits. It was believed that if these goals could be attained then there would be a high probability that the other-sized ATDs (5th percentile female, 95th percentile male and 6 year old child) would produce PEC within the FMVSS 208 limits. These goals were:

Head Injury Criteria (HIC)	750
Chest Resultant Acceleration	45 G_R
Femur Compressive Loads	7.5 kN (1700 lbs.)

In addition to meeting these specifically defined upper limits, it was determined that upper torso belt loads would be limited to 6.7 kN (1500 lbs.).

- Passivity and Comfort Considerations

The FMVSS 208 implementation dictates that all automobiles manufactured or marketed in the United States by 1984 must afford passive protection for front seat occupants. In light of this, the decision was made that the belt system developed under this contract should have the capability of passivity. It was also decided, in consultation with the Contract Technical Manager, that comfort (implying greater consumer acceptance, thereby use) to the occupant should also be considered. The primary comfort consideration in a passive belt system (according to Dr. Woodson of Manfactors Corporation) is the 'scrubbing' effect of the upper torso belt on the occupant's shoulder when the emergency locking retractor (ELR) is positioned inboard. It was decided that the ELR in this system would be positioned outboard of the occupant. Discussions with Drs. Woodson and Black of Manfactors Corporation aided in the final choice of the ELR, D-Ring and anchor point locations.

- Force Limiting Considerations

The Takata-Kojyo Company of Japan was selected as the supplier of force limiting energy absorbing belt material for several reasons:

Their webbing produced excellent force deflection properties and upon short notice they could produce webbing with accurate force limiting properties in the 2.2 kN (500 lbs.) to 8.9 kN (2000 lbs.) range.

The webbing provided excellent indication of use due to the clearly visible broken belt fibers after loading.

Their webbing was production feasible, consumer acceptable (its appearance is that of conventional webbing, but slightly thicker) and its availability was immediate and economical.

Due to the ease of availability of this material it was decided that two levels of force limiting would be evaluated (6.7 kN (1500 lbs.) and 4.4 kN (1000 lbs.)). Consideration was given to one other device in production that was advertised to be an energy managing and use indicating product. A.B. Stil of Sweden manufactures a web shredding D-ring and, since some of these D-rings were available to the program, it was decided that they also would be evaluated.

- Belt Pretensioning Considerations

In general, passive belt systems require that more webbing be stored on the reel of the ELR after belt deployment. This additional length of webbing increases the 'spool off' length normally observed when active belt systems are used for occupant protection in crash situations. In systems designed to limit the forces in the belt by elongation (be it metal forming, webbing shredding or webbing stretching) this 'spool-off' problem is compounded by the very nature of the energy managing mechanism. The loss of effective stroking distance dictated by the above requirements is of even higher concern when the available space of a small car occupant compartment is considered.

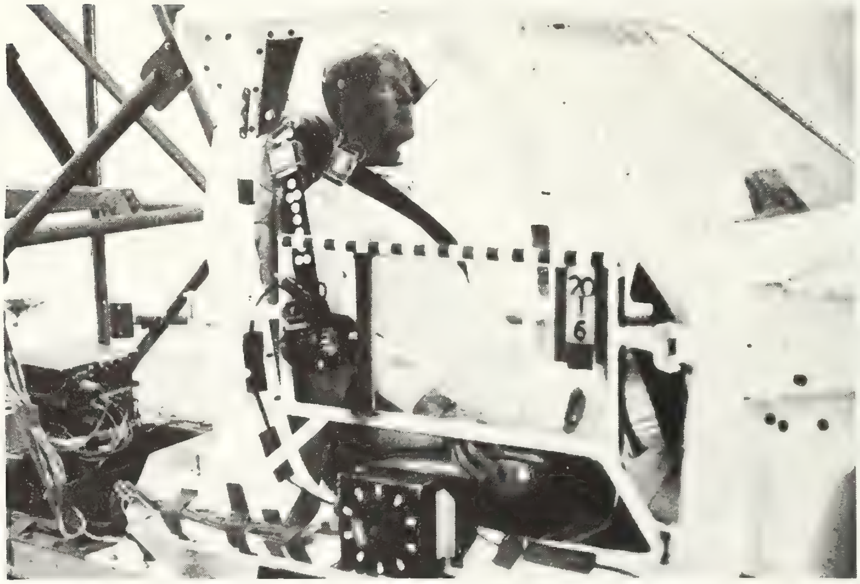
For these reasons it was determined that the use of some sort of belt pretensioner would be investigated.

There were two commercially available devices that showed promise as belt pretensioners at the outset of this program. One (Figure 2.0-1), a Pelton wheel device mounted on an ELR is manufactured by Repa, a German company. For operation the unit requires a crash sensor and power source to fire a powder charge. The expanding gas drives a piston that forces a fluid over the Pelton wheel attached to the ELR spool. The direction of rotation of the spool is such that the belt is tightened on the spool and tension is produced in the webbing. The other (Figure 2.0-2) was a linear pyrotechnic device manufactured by FFV Sweden. Upon crash sensing, a powder charge is fired and the expanding gas drives a piston to which a cable and D-ring are attached. In the configuration reported herein the webbing was pretensioned and the 'spool off' was taken up by the belt being pulled through 2 D-rings (Figure 2.0-2). Since definitive data was scarce for both devices it was decided that both would be used in the evaluation stage. The Repa unit, being closer to a production piece of hardware, was chosen as the primary pretensioner.

In summary, the definition of the force limited restraint system, based upon the foregoing descriptions was as follows:

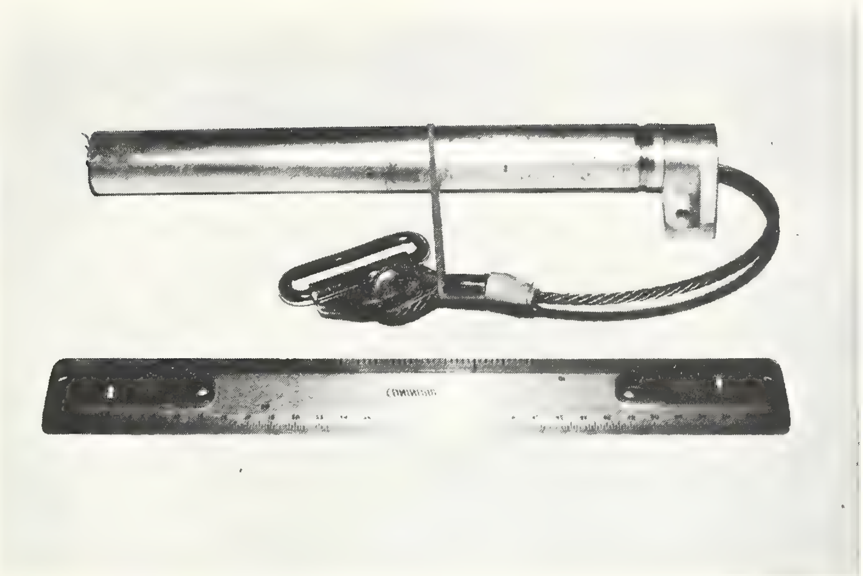
An ELR (incorporating the Repa belt pretensioner) mounted in the front door of the Chrysler L-body would allow the energy managing webbing to proceed upward just forward of the door to B-pillar junction and travel through a D-ring, attached to the door, down across the upper and lower torso of the occupant and be terminated at a solid anchor point on the inboard side of the vehicle front seat. An energy managing knee bar would be placed approximately four inches in front of the knees of a 50th percentile male sized ATD when the seat was placed in the mid seating position for the purpose of controlling the lower extremities (hips, femurs, etc.) loads and displacements.

(a)



(b)

Figure 2.0-1 REPA BELT PRETENSIONER UTILIZED IN THE FORCE LIMITING BELT SYSTEM



(a)

(b)

Figure 2.0-2 FFV BELT PRETENSIONER UTILIZED IN THE FORCE LIMITING BELT SYSTEM

3.0 DEVELOPMENTAL COMPUTER SIMULATIONS

Concurrent with the restraint system definition phase described in Section 2.0 of this report a developmental analytical effort to determine performance criteria was carried out by means of three-dimensional computer simulations. The program used in this study (referred to as Task 2) was the Calspan-developed Crash Victim Simulation version 18C, (CVS III).

The objective of Task 2 was to create a data base of simulations which could then be used as a basis for predicting performance trends as a function of changes in test conditions, restraint system parameters, ATD size, etc.

As this effort progressed, it became apparent to the authors and the CTM that, in order to effectively predict occupant performance trends, it was necessary to tailor the simulation input data to generate output values more closely aligned with measured sled data. This entailed creating a separate simulation run for each input change in order to accurately assess the 'cause and effect' of altering each input parameter. It was agreed that a data base of selected simulations closely aligned to sled data was of greater future value than a data base containing many simulations representing more crude approximations of occupant response. Therefore, the stored developmental simulation data base consists of nine runs which incorporate all velocity changes and each of the belt configurations under investigation. It is anticipated that this stored data will be of value in the future as more of the current unknowns become available (i.e., ATD segment and joint characteristics, different size ATD models, dynamic vehicle interior force-deflection properties, etc.) which can then be incorporated into the current input stream.

The computer simulations for this study were executed on the Univac 1108 computer system located at Edgewood, Maryland. A HARRIS 1600 Remote Communications Process (RCP) is installed as government-furnished equipment at the Advanced Technology Center of Calspan Corporation. It is the property of the NHTSA and has been made available to Calspan for remote batch processing on government-furnished computer facilities for government contracts.

The computer simulations were run at the Edgewood facility to fulfill the program requirement that all input and output data be immediately accessible to the Contract Technical Manager (CTM) in Washington and that all of the pertinent input and output data be stored at Edgewood for future use.

It is noted that the CVS III program as used in this reported work is not intended to establish absolute values, but rather to aid in evaluating trends caused by varying input data. With regard to this particular belt study, it must be understood that the CVS III version available for use at this time (Version 18C) does not take into account such phenomena as belt slippage on the ATD, actual belt friction, irregular belt stretch and belt rotation from the lower anchor points to the ATD H-points.

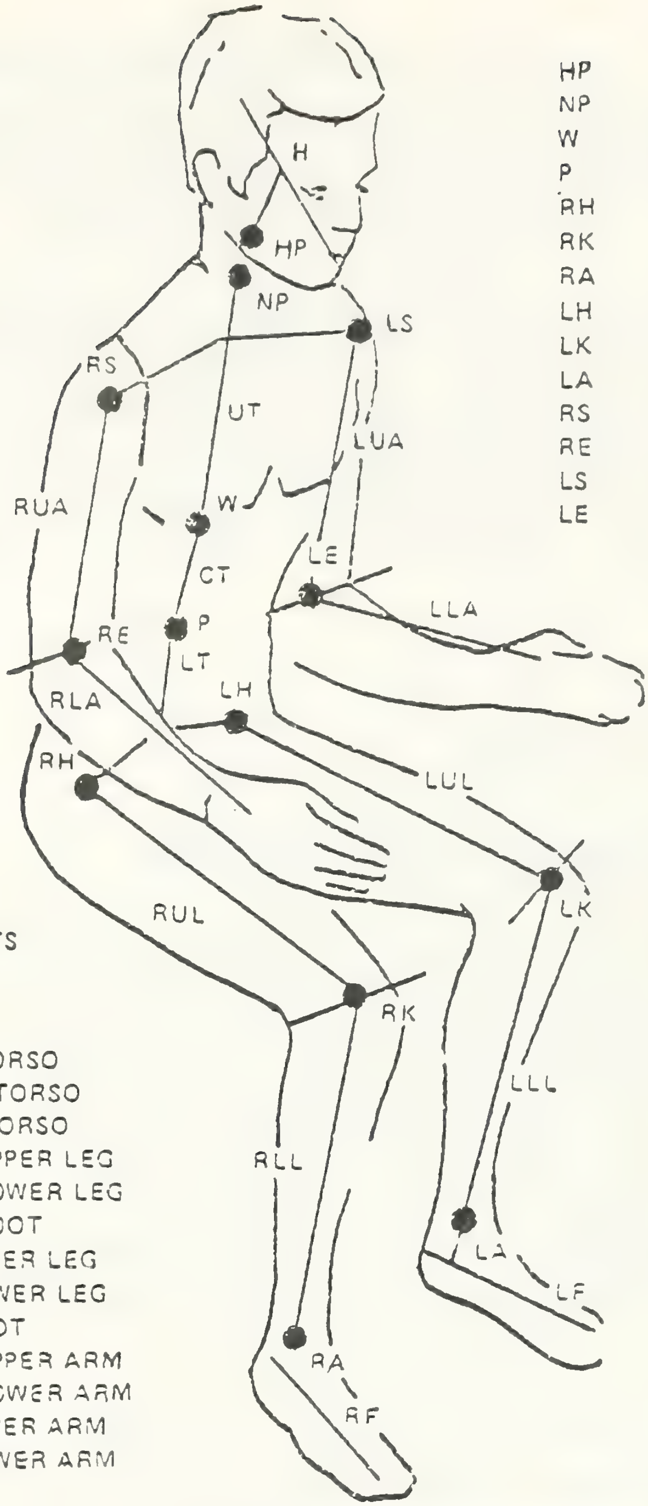
This program is described in detail in Reference 1, but for the sake of completeness a brief description is presented below.

3.1 Calspan 3-D Crash Victim Simulation Program

The manner in which the crash victim has been modeled in most applications of the simulation to date is illustrated in Figure 3.1-1. The human body is represented as being composed of 15 segments connected by 14 joints. The simulated torso is articulated in three segments and the neck is approximated as a single segment with two joints. All joints are usually considered to be ball and socket joints except the knees and elbows which, because they effectively permit only a single degree of freedom, are represented as pin joints. Ellipsoids are used to approximate the surface of each body segment.

The computer program requires literally hundreds of inputs to describe the ATD model parameters which include the length, weight, center of gravity location and principal moment of inertia about each of three orthogonal axes of each segment, and the joint torque characteristics as a function of the angular displacement and velocity of each joint. In addition inputs are required that include the geometric and compliance properties of the vehicle interior surfaces, a tabular or functional definition of the deceleration time history of the vehicle, and the occupant restraint characteristics (e.g., belts, knee bars, etc.).

	JOINTS
HP	HEAD PIVOT
NP	NECK PIVOT
W	WAIST
P	PELVIS
RH	RIGHT HIP
RK	RIGHT KNEE
RA	RIGHT ANKLE
LH	LEFT HIP
LK	LEFT KNEE
LA	LEFT ANKLE
RS	RIGHT SHOULDER
RE	RIGHT ELBOW
LS	LEFT SHOULDER
LE	LEFT ELBOW



	SEGMENTS
H	HEAD
N	NECK
UT	UPPER TORSO
CT	CENTER TORSO
LT	LOWER TORSO
RUL	RIGHT UPPER LEG
RLL	RIGHT LOWER LEG
RF	RIGHT FOOT
LUL	LEFT UPPER LEG
LLL	LEFT LOWER LEG
LF	LEFT FOOT
RUA	RIGHT UPPER ARM
RLA	RIGHT LOWER ARM
LUA	LEFT UPPER ARM
LLA	LEFT LOWER ARM

Figure 3.1-1 BODY DYNAMICS MODEL

The vehicle interior and seating surfaces are represented in the program input as planes, each requiring a force-deflection characteristic in either tabular or polynomial form. Contact between selected occupant segments and interior planes is designated in the allowed contact matrix which is also part of the program input.

The extensive output from the program is controllable through input code and includes such items as the components and resultants of linear and angular accelerations, velocity and displacement of specified segments, joint angles and torques, location and force developed at points of contact with the vehicle, and belt loads. A simplified representation of occupant kinematics is also provided (designated as a printerplot) showing the location of body segment joints and centers of gravity at specified points in time. The program generates a binary unformatted tape (or disk), referred to as Unit 8, which may be accessed to list tabular time histories and to plot, as a function of any variable, any other variable listed in the tabular time histories.

Vehicle interior geometry is normally obtained from either production drawings or actual measurements taken from the vehicle under investigation. The contact surface data are usually input to the CVS III program as a series of appropriately sized and placed flat planes although when necessary, a contact surface may be input as an ellipsoid.

3.2 CVS III Input Parameters

Initial input parameters to the CVS III program for the developmental analytical task were based upon the restraint system definition described in Section 2.0 of this report. These input parameters consisted of: dimensions of the occupant space determined from a full scale drawing of the Omni-Horizon supplied by Chrysler, typical force-deflection characteristics of contact panels that had been determined from previous CVS III simulations of small cars (Reference 2), an energy managing knee bar force-deflection curve estimated on the desired performance characteristics of the system to be integrated into

the body buck, belt force-deflection characteristics based upon available data on standard and energy managing webbing (References 3 and 4) and a preliminary 48 Km/hr (30 MPH) barrier crash pulse supplied by the Chrysler Corporation.

Examples of some of the modifications to these input parameters considered necessary during development are given below.

- Detailed measurements were taken from a full scale Chrysler L-body drawing which was supplied to Calspan several weeks prior to delivery of the body-in-white. These measurements were used to identify the planes to be input to the program as contact surfaces. After fabrication of the body buck some modifications to input geometric measurements were necessary and these alterations were made in the existing input modules.

- Initially, typical force-deflection characteristics were assigned to most of these interior surfaces. During the course of baseline sled testing, some of the force-deflection characteristics were modified to more closely approximate observed and measured sled data. Examples of these were the belt force-deflection characteristics and the energy managing kneebar. As mentioned above, the belt force-deflection characteristics were derived from the available data on standard nylon webbing, the force-limiting levels anticipated and dummy compliance measurements. It became apparent during the course of sled testing that dynamic spool-off should also be incorporated into the belt force-deflection curves. Figures 3.2-1 through 3.2-7 display the belt force-deflection 'best estimates' used for these developmental runs. Belt force-deflection characteristics were further refined in Task 4 and will be discussed in greater detail in Section 4.2.

- The force-deflection properties of the Calspan designed kneebar were considered to be critical to occupant motion during a simulation and a typical kneebar force-deflection curve did not simulate this design properly. The maximum femur load versus maximum kneebar penetration measured for the first series of sled runs which used the final kneebar design (runs 2016 through 2032)

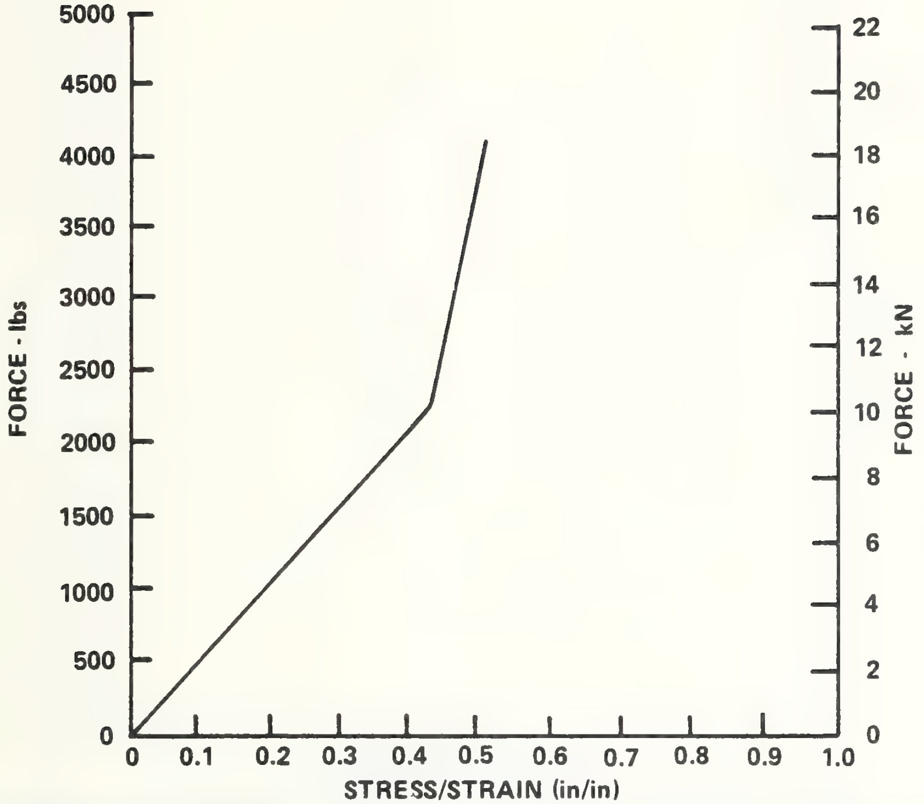


Figure 3.2-1 PRELIMINARY CURVE A – NYLON WEBBING NO PRELOADING

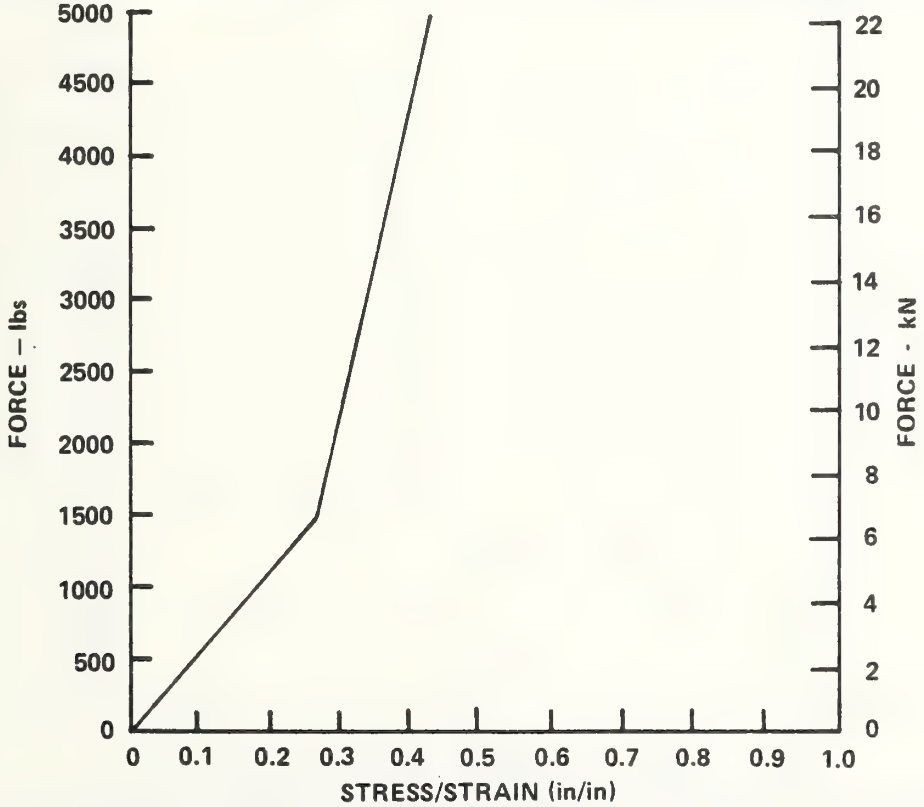


Figure 3.2-2 PRELIMINARY CURVE B – NYLON WEBBING PRELOADED

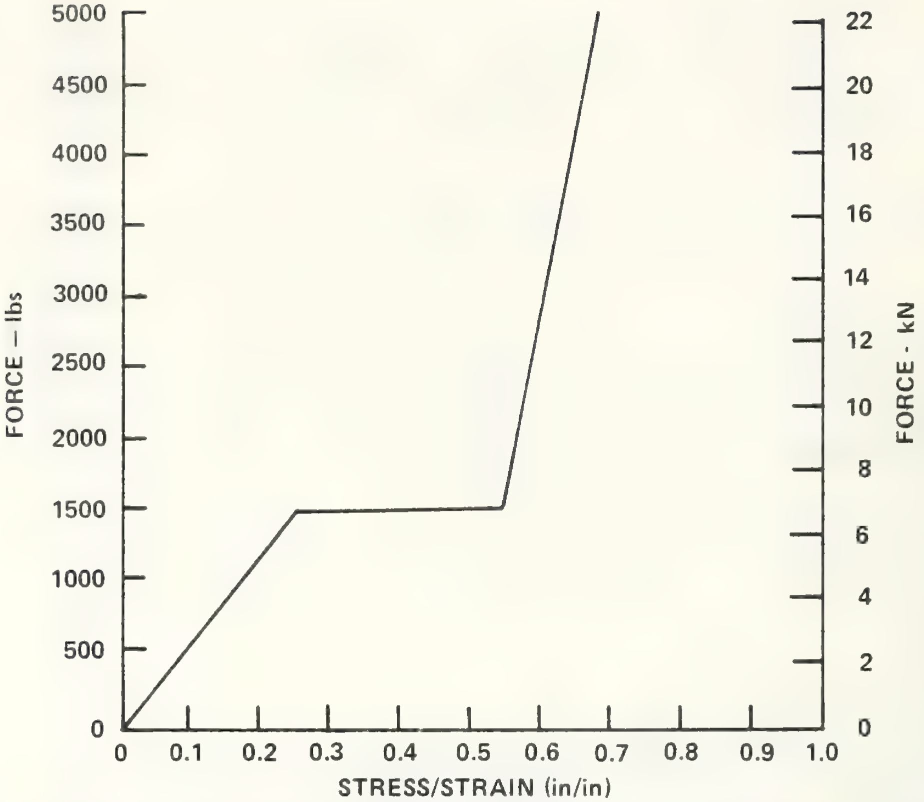


Figure 3.2-3 PRELIMINARY CURVE C – 6.67 kN (1500 lbs) FORCE-LIMITING WEBBING NO PRELOADING

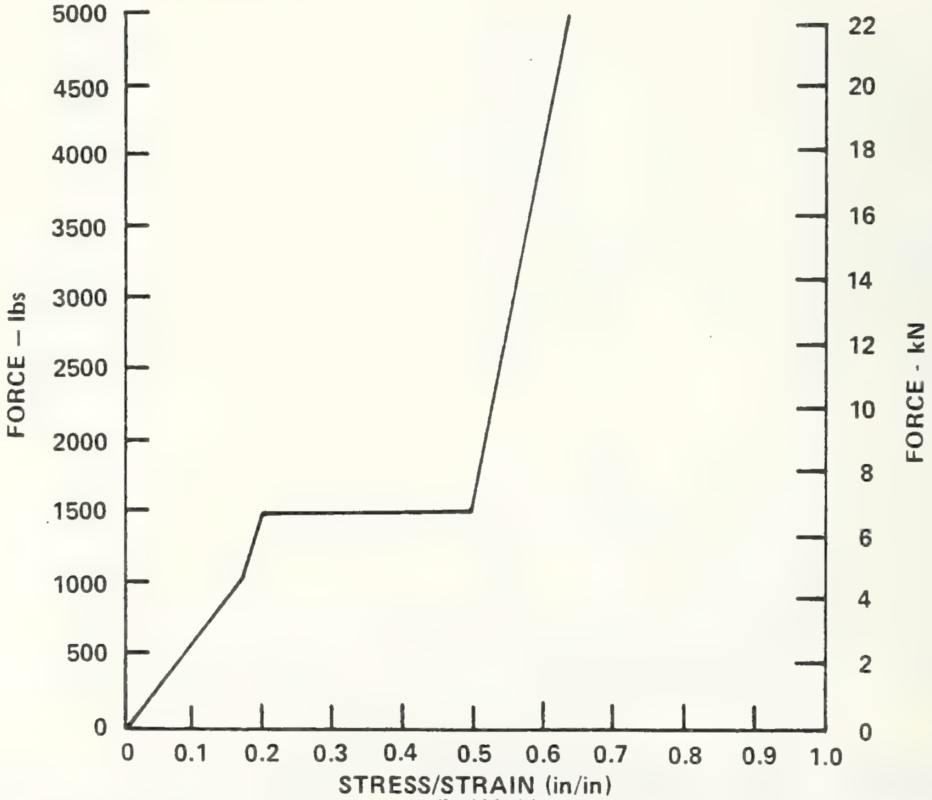


Figure 3.2-4 PRELIMINARY CURVE D – 6.67 kN (1500 lbs) FORCE-LIMITING WEBBING PRELOADED

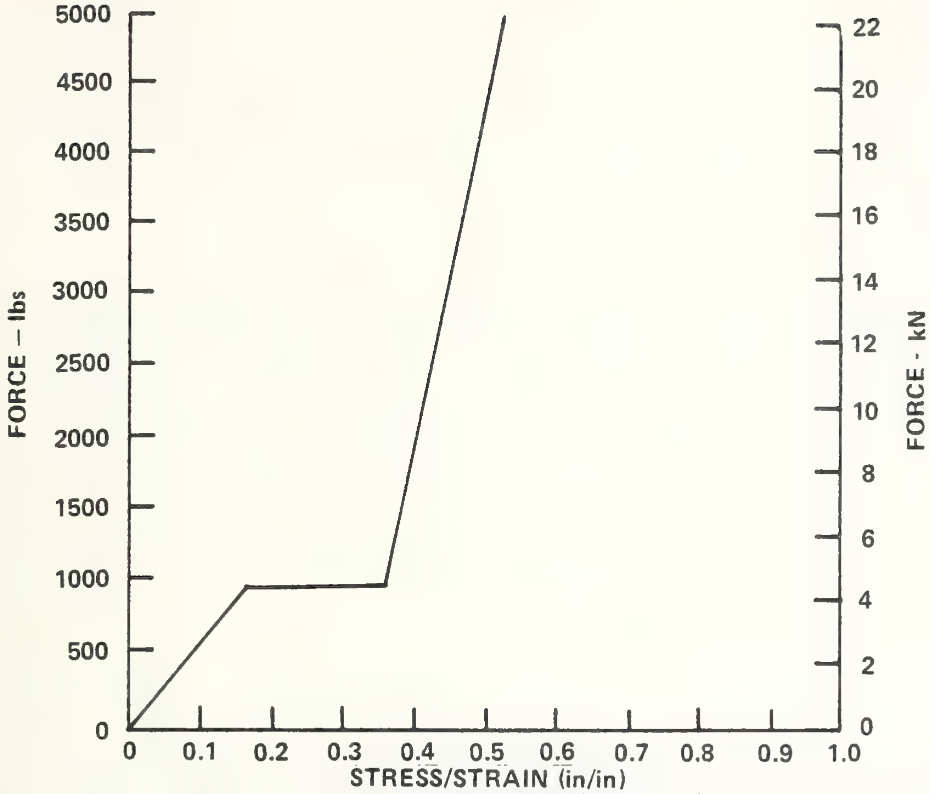


Figure 3.2-5 PRELIMINARY CURVE E — 4.44 kN (1000 lbs) FORCE-LIMITING WEBBING PRELOADED

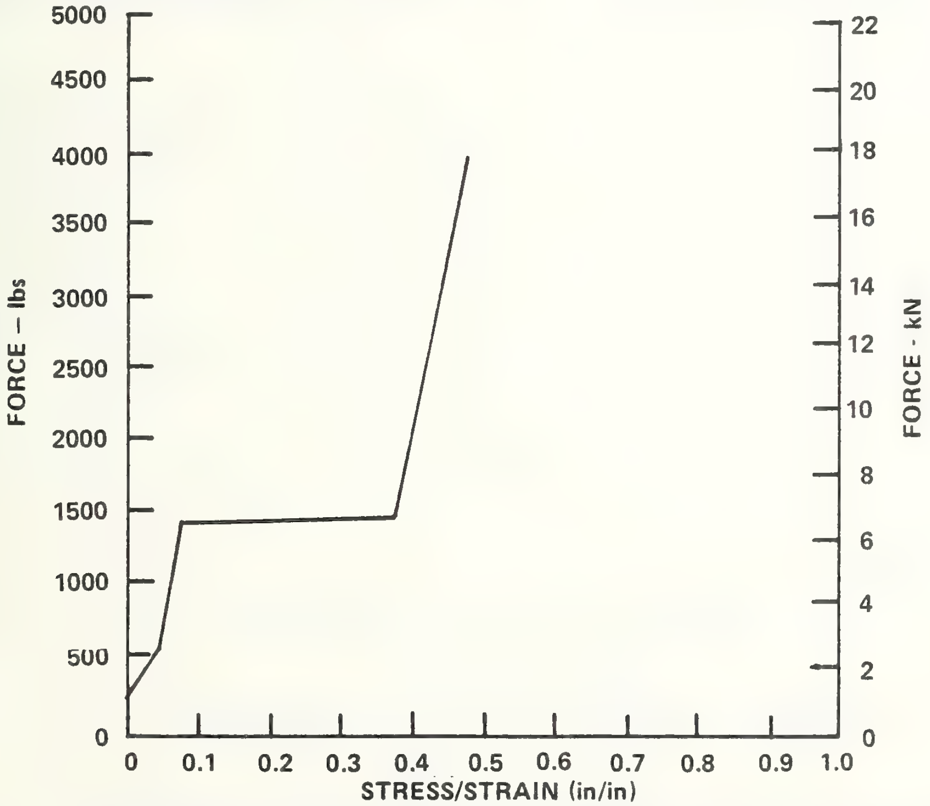


Figure 3.2-6 PRELIMINARY CURVE F — 6.67 kN (1500 lbs) FORCE-LIMITING WEBBING 1.33 kN (300 lbs) STATIC PRELOADING

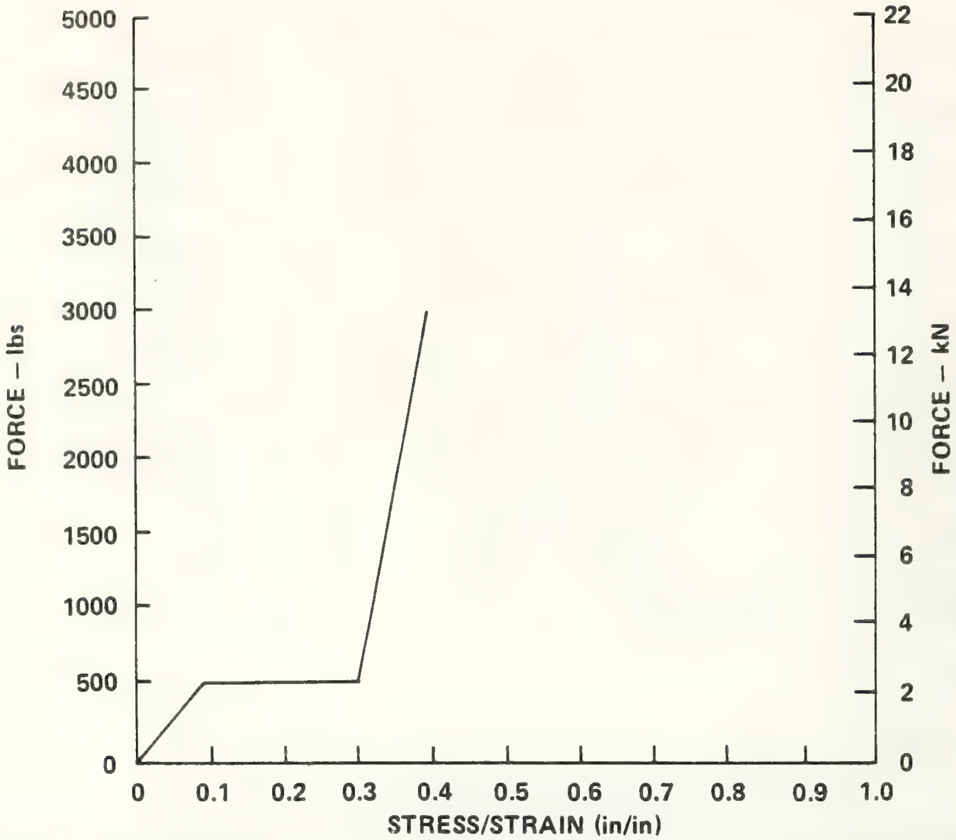


Figure 3.2-7 PRELIMINARY CURVE G – 2.22 kN (500 lbs) FORCE-LIMITING WEBBING LAP BELT

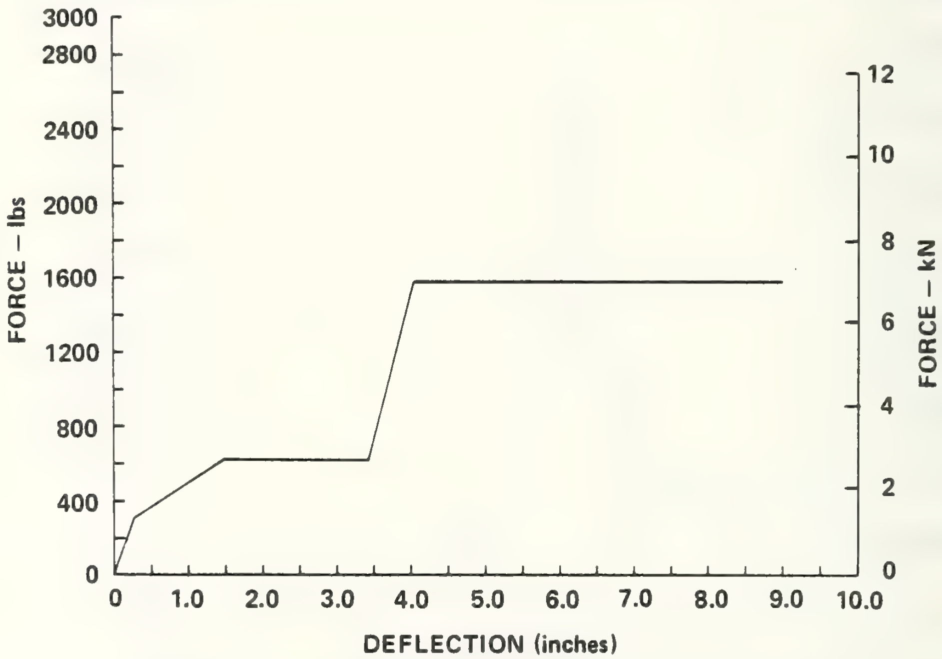


Figure 3.2-8 KNEEBAR FORCE VS DEFLECTION

were plotted and input to the simulation program. The output data from simulations using this force-deflection function indicated that this curve was too 'stiff' and these data were then modified generating more realistic occupant responses. Figure 3.3-8 displays the final kneebar force-deflection curve.

- The original computer simulations were run using the 48 Km/h (30 MPH) Chrysler-supplied acceleration-time history plot. Subsequently, an updated barrier crash deceleration pulse was acquired from the CTM. After a metering pin was fabricated to simulate this pulse the sled pulse check acceleration-time history data were incorporated into the simulation input. Likewise, actual sled pulse data for both 64 Km/h (40 MPH) and 72 Km/h (45 MPH) tests were input to the simulations for these velocities.

Considerable effort was expended at this time in creating both the structured Fortran input decks and the Univac 1108 command language to allow for storage and access of input and output data at the Edgewood facility. Also, it became apparent that the extensive output created by this simulation program was not conducive to 'production running', but was better suited for developmental simulations. The program was modified to output larger time increments onto the tabular time histories by changing an input command. This allowed for quick analysis of the data and a decision as to whether or not to plot the entire time history. The plotting capability of the CVS III program is especially adaptable to this belt study in that all the data is contained on a visual analysis aid and can be easily compared with the sled data. The disadvantage of plotted data lies in the fact that the Harris terminal at Calspan is not equipped with a plot output device, and therefore plots are mailed from Edgewood causing a delay of several days time.

3.3 CVS III Output

The stored Task 2 output data consists of nine three-dimensional computer simulations of the 50th percentile male right front passenger, restrained by the following belt configurations:

- Baseline system with nylon webbing and conventional ELR
- Dynamic preloaded system with nylon webbing
- Dynamic preloaded system with force-limited webbing
- Static preloaded system with force-limited webbing
- Force-limited system with no preloading
- Two levels of force-limiting with preloading
- Preloaded, force-limited system with an active force-limited lap belt
- Sled velocity changes of 54 Km/h (34 MPH), 64 Km/h (40 MPH) and 72 Km/h (45 MPH).

Using the simulation of sled run 2017 as a data base, input parameters were refined until a reasonable correlation between sled and simulation data was attained. Seventeen development simulations were generated, each with a change of one input parameter and the output data was analyzed to determine the affect of this change on occupant responses. Figures 3.3-1 and 3.3-2 illustrate the progression in kinematics and head excursion experienced through this series of 17 simulations (runs 2017A through 2017Q).

Figure 3.3-1 displays the printerplot output of the CVS III program. Printerplots were selected and overlaid at significant time intervals giving a visual display of the occupant kinematic responses generated by these particular simulations.

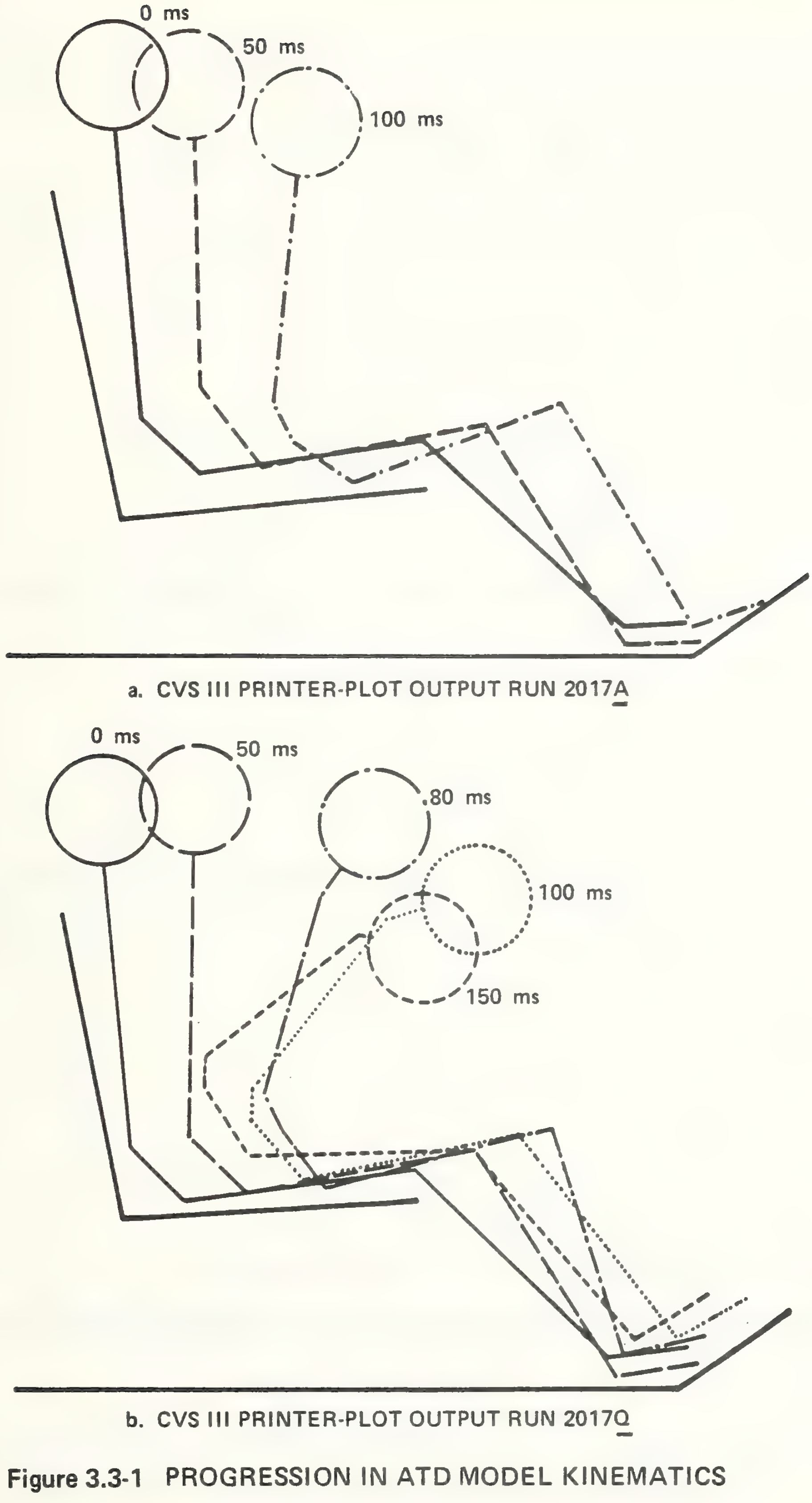
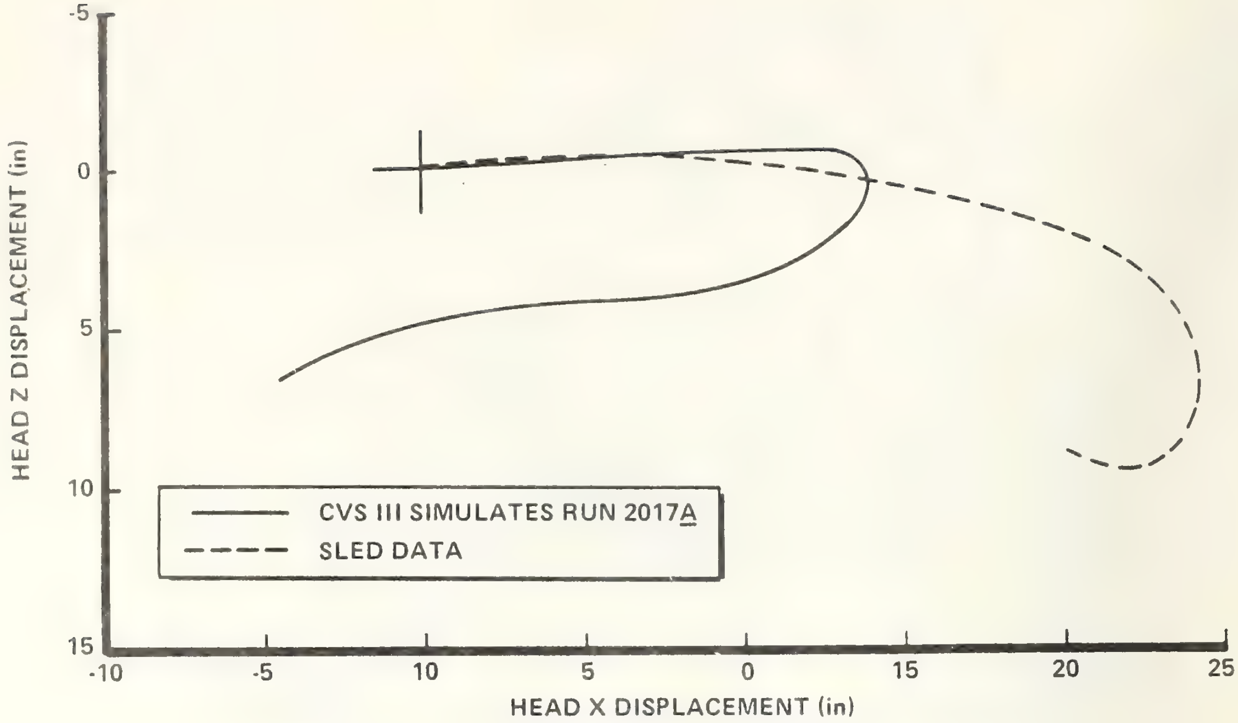
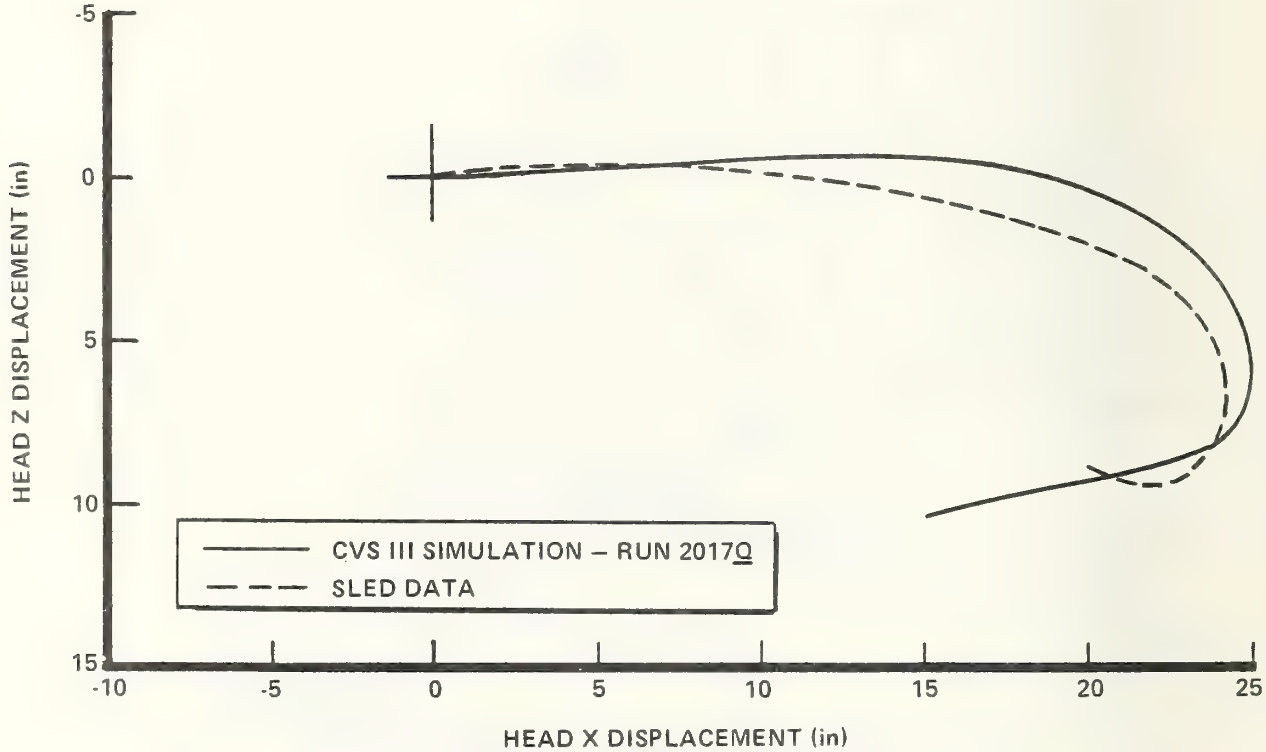


Figure 3.3-1 PROGRESSION IN ATD MODEL KINEMATICS



a. RUN 2017A



b. RUN 2017Q

Figure 3.3-2 PROGRESSION IN ATD HEAD EXURSION COMPARISONS

Figure 3.3-2 displays an example of the plot output option of the CVS III program. Head excursion in the X and Z directions generated by the simulations are overlayed with sled data taken from high speed films.

The input parameters generating the most significant improvement in ATD model kinematic and head excursion comparisons were the creation of a new contact ellipsoid and a modification in the windshield force-deflection characteristics.

As can be noted from Figures 3.3-1a and 3.3-2a, respectively, computer output ATD kinematics and head forward excursion appear to be quite restricted. It was determined that belt interaction with the upper torso ellipsoid was not representative of actual ATD conditions and restricted motion in the Z direction. A new contact ellipsoid was generated which encircled both the upper and center torso ellipsoids and belt interaction with this ellipsoid allowed the ATD model to respond in a more realistic manner, as seen in Figures 3.3-1b and 3.3-2b.

The polynomial force-deflection characteristics normally associated with windshield/head contact caused a sudden reversal in head motion in the simulation output data restricting the motion in the X direction (Figure 3.3-1a and 3.3-2a. Consequently, a force deflection function which created no force on the head at windshield contact, but allowed the analyst to determine if and when contact was made, was input to the program. This allowed the simulated ATD head to move forward unrestricted until the belt forces came into play or head contact was made with a different interior surface. It was considered to be outside the scope of this particular program to experimentally determine an effective mutual force-deflection curve for the sled buck windshield.

The final Task 2 simulations were created using the input parameters of Run 2017Q and varying only the belt characteristics and/or velocity change. Table 3.3-1 lists the sled run number, the relevant belt force-deflection curve (see Figures 3.2-1 through 3.2-7 and a brief description of the sled run being simulated. Because these simulations are considered developmental, they have

Table 3.3-1

TASK 2

DEVELOPMENTAL COMPUTER SIMULATIONS

SIMULATION OF SLED RUN NUMBER	BELT FORCE-DEFLECTION FUNCTION CURVE	DESCRIPTION
2011	A	BASELINE SYSTEM WITH NYLON WEBBING NO-PRELOADING
2010	B	DYNAMIC PRE-LOADED SYSTEM WITH NYLON WEBBING
2019	C	FORCE-LIMITED WEBBING WITH NO PRE-LOADING
2017	D	DYNAMIC PRE-LOADED SYSTEM WITH FORCE LIMITED WEBBING
2018	D,G	DYNAMIC PRE-LOADED SYSTEM WITH FORCE-LIMITED WEBBING AND ACTIVE LAP BELT
2027	D	DYNAMIC PRE-LOADED SYSTEM WITH FORCE-LIMITED WEBBING @ 64 Km/h (40 MPH)
2031	D	DYNAMIC PRE-LOADED SYSTEM WITH FORCE-LIMITED WEBBING @ 72 Km/h (45 MPH)
2032	F	STATICALLY PRE-LOADED SYSTEM WITH FORCE-LIMITING WEBBING @ 72 Km/h (45 MPH)
2016	E	DYNAMIC PRE-LOADED SYSTEM WITH LOWER LEVEL FORCE-LIMITING WEBBING

not been included in the output data plots (Appendix B). Storage of input and output data will be discussed below.

- Computer Facilities and File Maintenance

The methodology for creating computer simulations was decided upon in consultation with the CTM. A system was generated wherein the input parameters were stored as separate elements in a disk file and these elements could be displayed, updated and executed in the demand mode. The output data was routed to Unit 8, a packed binary disk file, as well as being printed and plotted. The naming convention of files and elements contains the sled run number of the simulated test preceeded by an "R" for input element or a "U8" for output Unit 8. A letter following the sled run number is used for job sequencing. This naming convention was adhered to whenever possible. Appendix B contains selected examples of current Univac command language necessary to access the simulation data stored at the Edgewood facility. More detailed information can be found in Reference 5.

Task 2 input parameters and output data are stored on tape 243412 which contains ten files. The first file, BKF3, consists of nine elements of input which can be accessed to create the output data found on files 2 through 10 or can be modified by a user to output new simulations. Files 2 thorugh 10 are packed binary files of output data. Tape 243412 contains the ten files listed in Table 3.3-2 (file one also lists the nine input element names).

Table 3.3-2

TASK 2 DATA STORED AT EDGEWOOD, MARYLAND

TAPE NO. 243412

INPUT PARAMETERS		OUTPUT DATA	
File No.	File - Element	File No.	File
1	BKF3 · R2010	2	U82010
1	BKF3 · R2011B	3	U82011B
1	BKF3 · R2016	4	U82016
1	BKF3 · R2017A*	5	U82017A
1	BKF3 · R2018	6	U82018
1	BKF3 · R2019	7	U82019
1	BKF3 · R2027	8	U82027
1	BKF3 · R2031	9	U82031
1	BKF3 · R2032A	10	U82032A

*Run R2017Q was re-named and stored as R2017A.

4.0 RESTRAINT SYSTEM TESTING AND EVALUATION

This section describes the restraint system developmental and evaluation sled testing (4.1) and the comparative computer simulations (4.2). Lateral impact sled tests are described in sub-section 4.3.

4.1 Developmental and Evaluation Sled Testing

- Sled Body Buck

A Chrysler Corporation L-body along with a steering wheel and column, instrument panel and two front seats was purchased for use on this program. The front half of the body (from the firewall to just aft of the B-pillars) was fabricated into a sled mounted body buck. The only reinforcing structures utilized were those required to accommodate repeated sled tests and these were all external to the occupant compartment. Figure 4.1-1 is a photograph of the body buck mounted on the 12 inch HYGE sled prior to a test.

While the outboard anchor point location and ELR positioning were fit to the L-body door a pipe and plexiglas structure was used during the testing to facilitate the sled mounted high speed motion picture coverage. Visible in the photograph is one of the onboard 100 ms per revolution clocks that were mounted in the field of view of the high speed cameras and the eight picture sequence cameras.

The lower half of the instrument panel was removed and a structure was fabricated to support the energy managing kneebar (Figure 4.1-2). The kneebar was designed to limit femur compressive loads to a range of 6.7 to 7.1 kN (1500 to 1600 lbs.) in an effort to maintain a knee stroking distance of approximately 23 cm (9 in.).

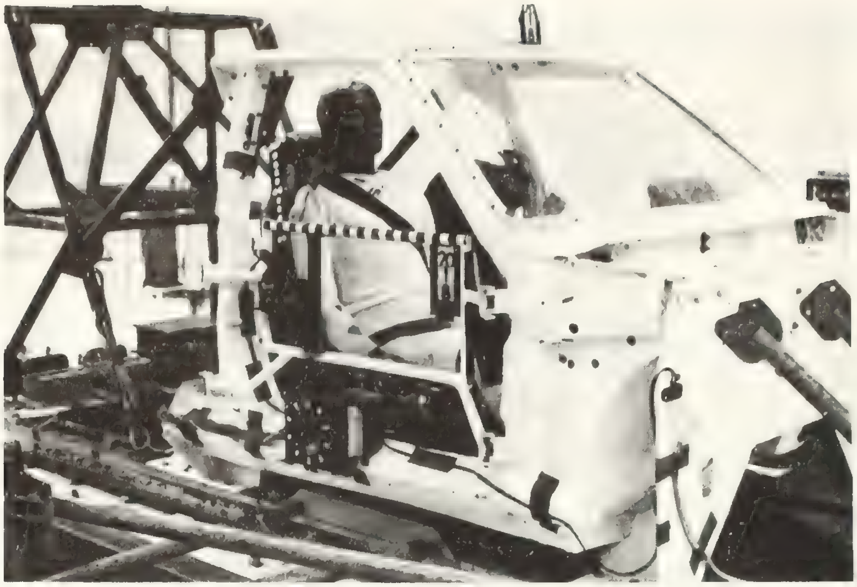


Figure 4.1-1 CHRYSLER L-BODY MOUNTED ON THE 12 INCH HYGE SLED

Figure 4.1-2 ENERGY MANAGING KNEE BAR IN CHRYSLER L-BODY

- Crash Pulse

Calspan was furnished a 48 Km/h (30 MPH) barrier crash pulse for the Chrysler L-body by the CTM. Calspan's sled prediction and metering pin design computer program was used to obtain the dimensions required to modify an existing metering pin for the HYGE sled. This new metering pin shape was determined by an iterative process to tailor the predicted acceleration time history to the barrier crash deceleration pulse. Figure 4.1-3 presents the results of a sled pulse check run of the metering pin design. Also displayed in this figure are the required 48 Km/h (30 MPH) barrier pulse (sled velocity, 55 Km/h (34 MPH)) and the computer program prediction of sled performance using this metering pin.

In addition to the 55 Km/h (34 MPH) sled testing, in keeping with the objectives of restraint system functioning at higher velocity changes, it was decided in consultation with the CTM that sled velocity changes of 64 Km/h (40 MPH) and 72 Km/h (45 MPH) would be attempted. Since there was no data available on barrier crash pulses of the Chrysler L-body at these higher speeds the assumption was made that for higher impact velocity the acceleration maximums would increase along with the time. Using these assumptions facility conditions were set up and the higher speed test results presented in this report were obtained using the typical sled acceleration pulses presented in Figure 4.1-4.

- Belt Anchor Point Locations

Based upon telephone conversations with Drs. Woodson and Black of Manfactors Corporation, evaluations of comfort and convenience considerations of a two point passive belt system anchor point location were determined. These anchor point dimensions are referenced from the H-points of a 50th percentile ATD in the mid seating position and were used on a basis for positioning the inboard (lower) anchor point and the outboard (upper) D-ring in the Chrysler L-body. Because of the requirement for passivity capability and the desire for mounting the ELR in the door (of the actual car) the outboard D-ring was positioned at dimensions that simulated door mounting in the L-body.

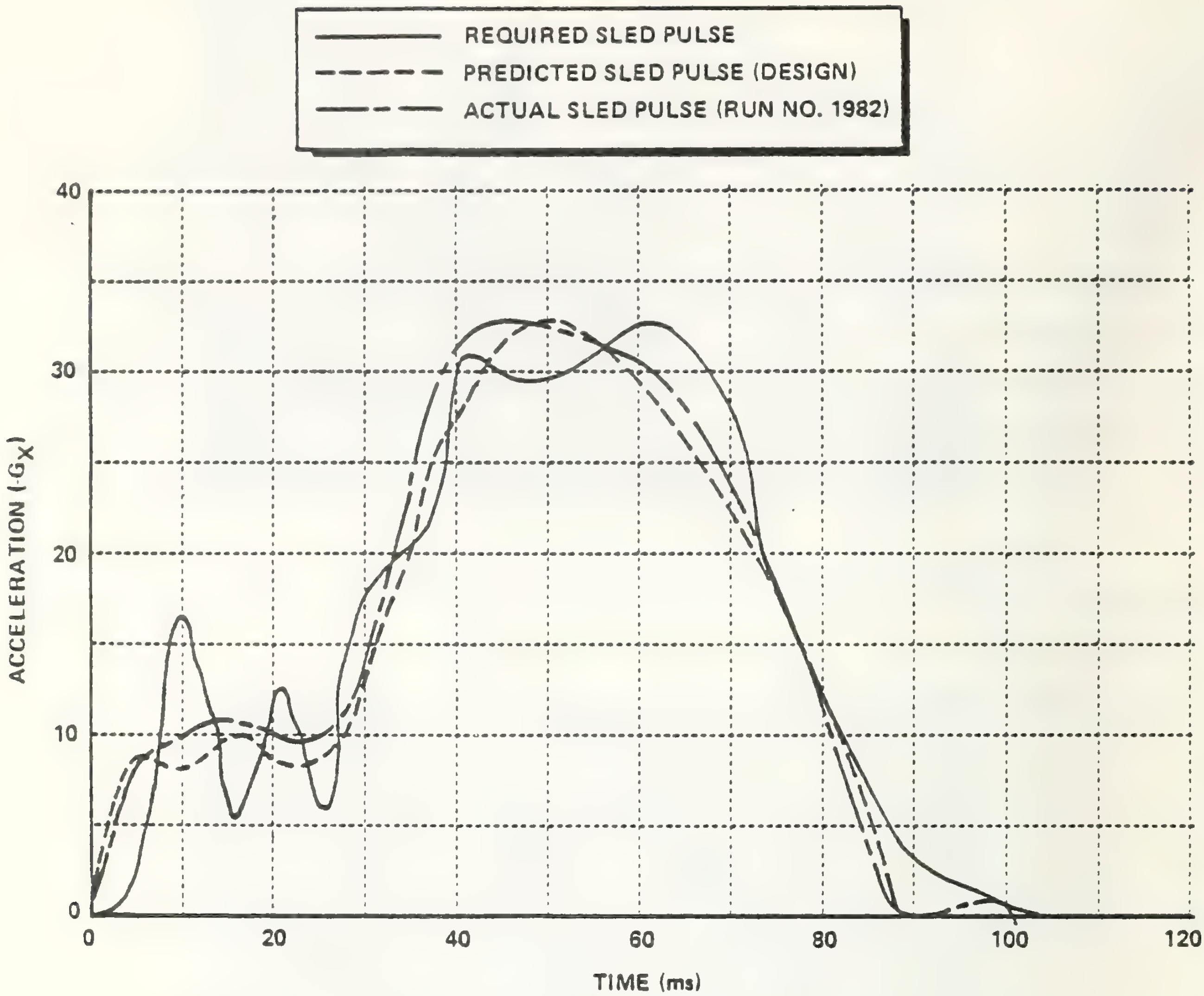


Figure 4.1-3 REQUIRED, PREDICTED AND ACTUAL SLED PULSE

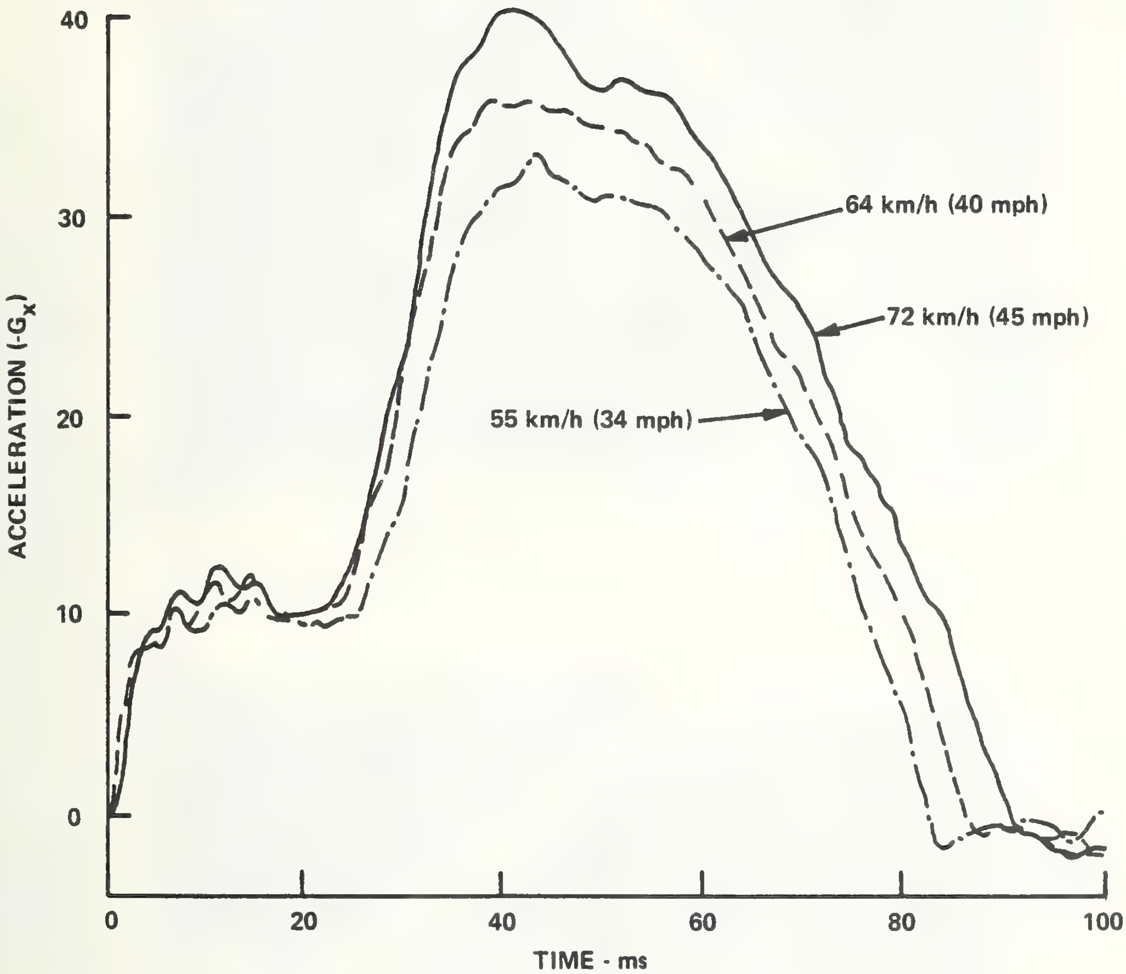


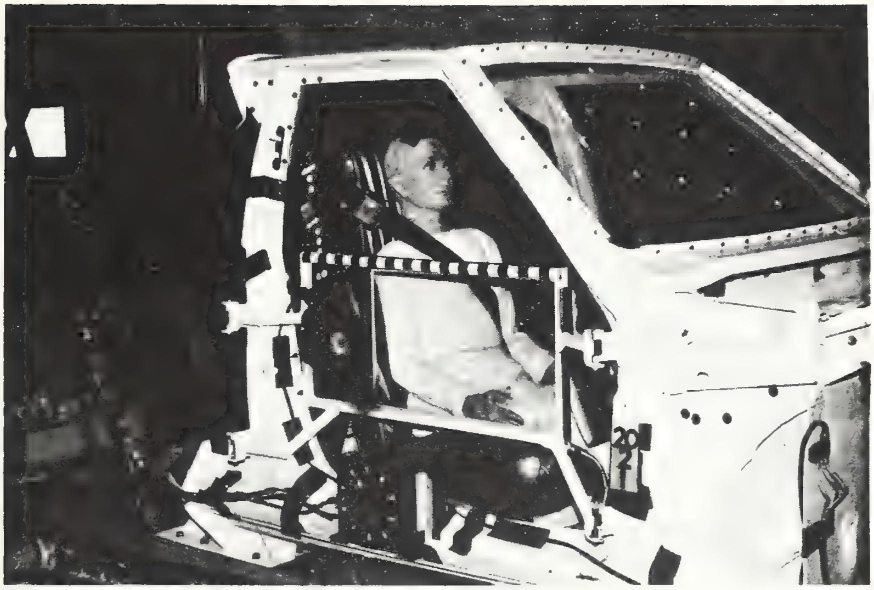
Figure 4.1-4 TYPICAL SLED ACCELERATION PULSES

This positioning (off the B-pillar) can be seen in Figure 4.1-2. Listed below are the dimensions provided by Manfactors and the dimensions of the baseline system used in the body buck.

	Manfactors	Omni
Outboard Upper Anchor Point	x = -24.8 cm (-9.75 in.) y = on the B-pillar z = -57.8 cm (-22.75 in.)	x = -25.4 cm (-10.0 in.) y = 5.1 cm (2.0 in.) z = -58.4 cm (-23 in.)
Inboard Lower Anchor Point	x = -3.8 cm (-1.5 in.) y = at edge of seat z = 16.5 cm (6.5 in.)	x = -3.8 cm (-1.5 in.) y = -7.2 cm (-3.0 in.) z = 16.5 cm (6.5 in.)

The ELR was mounted in a position that would place it inside the front door (below the window) of the L-body, a non-locking D-ring was attached to a plate that was attached to the B-pillar simulating the upper door anchor point location and the webbing, after going through the D-ring, transversed down across the ATD's upper and lower torso to the inboard anchor point (Figure 4.1-5).

It should be noted that the Manfactors dimensions for the inboard anchor point specify that the belt be attached to the seat. For the work reported here this was not a practical procedure since the number of seats available for sled testing was extremely limited. The lower anchor point was positioned as close to the edge of the seat as possible and attachment was made to an angle iron that was mounted to the body buck. Provisions were made to move the anchor point in the X-direction as the seat moved forward or aft of the mid seating position. This mechanism can be seen in Figure 4.1-5b.



(a) OUTBOARD CONFIGURATION

(b) INBOARD CONFIGURATION

Figure 4.1-5 PASSIVE BELT SYSTEM DEPLOYMENT

• Energy Managing Kneebar

When a torso belt only is used as the major component of a restraint system it is necessary that a device be incorporated into the system to control both the femur compressive forces and the knee excursion. For the development of this reported system it was decided that femur loads on the 50th percentile male ATD be held in the neighborhood of 7.1 kN (1600 lbs.). It was also determined that this level of loading be controlled with a knee penetration of between 10 to 13 centimeters (4 to 5 inches). A kneebar was designed and installed into the sled body buck. The original design used hexcel aluminum honeycomb`as the energy managing agent (1/4-5052-.0007, 1.6 lb) with a sheet of 1.27 cm (1/2 inch) insulite covering for load distribution. The dimensions of the honeycomb were 17.78 cm H X 60.96 cm L x 15.24 cm D (7 in. H.X 24 in. L. X 6 in. D.). The first configuration (designated as knee bar no. 1) provided femur loads that were slightly higher than desired (7.6 kN (1700 lbs.)) and penetration that was too low (5 cm (2 inches)). While the loads were tolerable and within the FMVSS 208 limits the lack of femur stroking distance indicated that ATD jackknifing would probably provide head contact with the instrument panel if higher velocity changes were attempted.

Removal of the center verticle support beam of the mounting structure (designated as knee bar no. 2) provided lower femur loads and higher penetration. (5.4 kN, 14.5 cm (1215 lbs., 5.7 in.)) These values were believed to be too low and too high, respectively, and a third modification was made (designated as kneebar no. 3).

This third modification consisted of placing a transverse angle iron 7.62 cm (3 inches) behind and 2.54 cm (1 inch) above the center of the honeycomb reaction pan. This configuration provided an average of 7.1 kN (1592 lbs.) femur loads and 11.7 cm (4.6 inches) penetration. All subsequent testing was performed using the kneebar no. 3 configuration. Figure 4.1-6 is a photograph of the post-test condition of kneebar no. 1 and Figure 4.1-7 is a photograph of the post-test condition of kneebar no. 3.

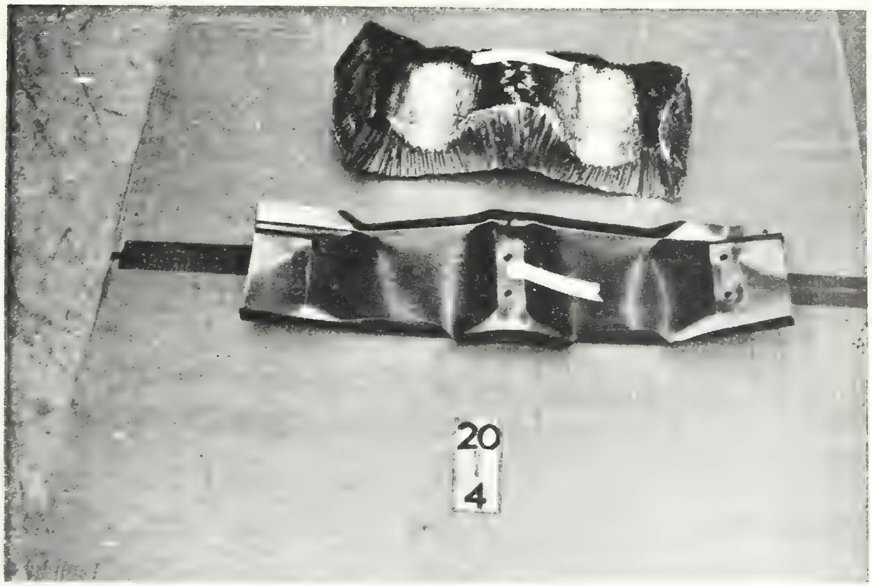


Figure 4.1-6 KNEE BAR NO. 1 POST TEST

Figure 4.1-7 KNEE BAR NO. 3 POST TEST

• Sled Testing

Two preliminary sled tests were conducted using a Volkswagen Rabbit passive belt system. The purpose of these tests was to determine if significant differences could be observed in the test results when the Volkswagen ELR was mounted inboard (the standard Rabbit installation) or outboard (the determined belt restraint system configuration). In addition to the production ELR and webbing system a Volkswagen seat was used. The energy managing kneebar was not totally a production one. Since only one unit was available it was cut in half and the right front passenger side was used for the first test (inboard retractor) and the driver side was used for the second test (outboard retractor). These two halves of the standard Volkswagen knee bar necessarily had to be supported at the inboard side (tunnel centerline) and therefore presented an artificially high degree of support structure which, in turn, produced high femur compressive loads in the ATD. During the test with the retractor mounted outboard the polyester webbing became bunched up in the upper D-ring and ripped. The mechanism of this failure is not well understood and the investigation of the failure was determined to be outside the scope of this work and therefore not pursued. Because of the off design configuration being tested at the time of failure, this cannot be construed as a bonafide belt failure of the VW restraint system. It is interesting to note that even with the webbing being torn at the D-ring, the timing into the test was such that the HIC and chest resultant acceleration were below FMVSS 208 upper allowable limits (Table No. 4.1-1).

Table numbers 4.1-1 through 4.1-4 present a summary of the results of the 40 sled tests conducted in the development and evaluation of the reported force limiting restraint system. The analog time history data traces from these tests are presented in Appendix A.

Table 4.1-1

ATD TEST DATA

RUN NO.	ATD	POSITION	H_R (G)	HSI	HIC	C_R^* (G)	CSI	FEMUR LOADS - kN (lbs) LEFT	RIGHT	P_R^{**} (G)
2008	50th	RFP	68	620	490	59	440	16.2 (3650)	8.0 (1800)	N/M
2009	50th	RFP	53	370	298	40	250	12.9 (2900)	8.3 (1875)	N/M
2010	50th	RFP	46	420	314	40	270	7.1 (1600)	7.0 (1575)	N/M
2011	50th	RFP	60	670	555	42	280	7.2 (1625)	7.5 (1700)	N/M
2014	50th	RFP	41	380	331	37	250	7.5 (1700)	LOST	N/M
2015	50th	RFP	55	580	513	36	260	5.7 (1300)	5.0 (1125)	N/M
2016	50th	RFP	40	290	240	36	180	6.8 (1550)	7.3 (1650)	N/M
2017	50th	RFP	44	300	230	36	200	7.1 (1600)	7.1 (1600)	N/M
2018	50th	RFP	> 100	680	478	32	190	5.7 (1300)	5.3 (1200)	N/M
2019	50th	RFP	59	560	466	38	210	6.8 (1550)	7.2 (1625)	N/M
2020	5th	RFP	140	–	–	60	–	2.6 (600)	3.1 (700)	N/M
2021	5th	RFP	54	–	–	40	–	2.8 (650)	2.8 (650)	N/M
2022	6 yr	RFP	138	> 2000	3252	80	700	N/M	N/M	N/M
2023	5th	RFP	63	880	734	41	310	2.5 (575)	2.7 (625)	N/M
2024	50th	RFP	66	740	589	50	420	6.3 (1425)	7.1 (1600)	N/M
2025	50th	RFP	46	470	390	35	210	6.4 (1450)	7.2 (1625)	N/M
2026	50th	RFP	54	490	390	34	150	6.2 (1400)	6.6 (1500)	N/M
2027	50th	RFP	49	480	436	33	220	7.0 (1575)	7.2 (1620)	N/M
2028	95th	RFP	> 200	1600	1080	48	400	6.2 (1400)	7.6 (1725)	N/M
2029	95th	RFP	42	320	292	34	230	6.1 (1390)	6.8 (1540)	N/M
2030	6 yr	RFP	> 200	> 5000	3840	80	710	N/M	N/M	N/M
2031	50th	RFP	85	1040	890	47	420	6.6 (1500)	7.6 (1725)	N/M
2032	50th	RFP	65	660	491	54	460	7.1 (1600)	7.3 (1650)	N/M
2116	50th	RFP	128	1080	672	54	380	6.4 (1440)	6.0 (1350)	N/M
2117	50th	RFP	35	300	253	33	220	6.2 (1390)	5.8 (1300)	N/M
2118	50th	DRIVER	200	1160	774	39	250	7.1 (1600)	6.7 (1500)	N/M
2119	50th	DRIVER	150	1200	830	46	350	6.9 (1560)	6.6 (1480)	N/M
2120	50th	DRIVER	>200	1560	811	65	470	6.9 (1550)	6.5 (1450)	N/M
2120	50th	RFP	62	550	432	30	200	6.7 (1500)	6.2 (1400)	N/M
2198	6 yr	RFP	116	3750	2794	52	600	N/M	N/M	N/M
2199	6 yr	RFP	135	5000	3820	60	620	N/M	N/M	N/M
2200	6 yr	RFP	158	> 5000	4657	57	600	N/M	N/M	N/M
2201	50th	RFP	62	1080	752	42	470	6.7 (1500)	6.8 (1520)	N/M
2202	50th	RFP	152	2300	1475	86	1000	6.7 (1500)	6.7 (1500)	N/M
2203	50th	RFP	70	900	706	38	260	6.2 (1400)	6.3 (1420)	N/M
2204	6 yr	RFP	70	740	532	40	220	N/M	N/M	N/M
2205	50th	RFP	51	250	207	33	230	N/M	N/M	26
2206	50th	RFP	48	250	215	32	220	N/M	N/M	37
2207	50th	RFP	36	220	171	47	260	N/M	N/M	32
2208	50th	DRIVER	64	756	592	19	80	N/M	N/M	20
2209	50th	DRIVER	33	200	162	20	80	N/M	N/M	19

*DEFINED AS EXCEEDING 3 ms DURATION

**PELVIS RESULTANT ACCELERATION - MEASURED ON LATERAL TESTS ONLY

–ELECTRICAL NOISE ON DATA CHANNELS PREVENTED DETERMINATION OF THESE VALUES

Table 4.1-2

SLED TEST CONFIGURATIONS

RUN NO.	ATD	ELR	POSITION	WEBBING kN (lb)	PRELOADER	LAP BELT	KNEE BAR	VARIABLE/COMMENT
2008	50th	VW	RFP	POLYESTER	NO	NO	VW	INBOARD ELR
2009	50th	VW	RFP	POLYESTER	NO	NO	VW	OUTBOARD ELR - BELT TORE AT 'D'-RING
2010	50th	REPA	RFP	NYLON	REPA	NO	1	
2011	50th	REPA	RFP	NYLON	NO	NO	1	
2014	50th	REPA	RFP	6.7 (1500)	REPA	NO	1	
2015	50th	REPA	RFP	6.7 (1500)	REPA	NO	2	
2016	50th	REPA	RFP	4.4 (1000)	REPA	NO	3	
2017	50th	REPA	RFP	6.7 (1500)	REPA	NO	3	
2018	50th	REPA	RFP	6.7 (1500)	REPA	2.2 Kn (500 lb)	3	
2019	50th	REPA	RFP	6.7 (1500)	NO	NO	3	
2020	5th	KLIPPAN	RFP	POLYESTER	NO	NO	3	
2021	5th	REPA	RFP	6.7 (1500)	REPA	NO	3	
2022	6 yr	KLIPPAN	RFP	POLYESTER	NO	NO	3	
2023	5th	REPA	RFP	6.7 (1500)	REPA	2.2 Kn (500 lb)	3	
2024	50th	KLIPPAN	RFP	POLYESTER	NO	NO	3	AB-STIL SHREDDING 'D'-RING
2025	50th	REPA	RFP	NYLON	NO	NO	3	AB-STIL SHREDDING 'D'-RING
2026	50th	VW	RFP	4.4 (1000)	FFV	NO	3	
2027	50th	REPA	RFP	6.7 (1500)	REPA	NO	3	64 Km/hr (40 mph)
2028	95th	REPA	RFP	NYLON	NO	NO	3	
2029	95th	REPA	RFP	6.7 (1500)	REPA	NO	3	
2030	6 yr	KLIPPAN	RFP	POLYESTER	NO	NO	3	ANCHOR POINT LOWERED 25 cm (10 inches)
2031	50th	REPA	RFP	6.7 (1500)	REPA	NO	3	72 Km/h (45 mph)
2032	50th	NO	RFP	6.7 (1500)	1.3 kN (300 lb) STATIC	NO	3	72 Km/h (45 mph)
2116	50th	KLIPPAN	RFP	NYLON	NO	NO	3	
2117	50th	REPA	RFP	6.7 (1500)	REPA	NO	3	REPEAT OF RUN 2017
2118	50th	REPA	DRIVER	6.7 (1500)	REPA	NO	3	
2119	50th	REPA	DRIVER	NYLON	NO	NO	3	
2120	50th	REPA	DRIVER	6.7 (1500)	REPA	NO	3	
2120	50th	REPA	RFP	6.7 (1500)	REPA	NO	3	
2198	6 yr[1]	REPA	RFP	NYLON	NO	2.2 Kn (1500 lb)	3	
2199	6 yr[1]	REPA	RFP	NYLON	NO	NYLON	3	
2200	6 yr[1]	REPA	RFP	NYLON	NO	NYLON	3	20 cm (8 in.) BOLSTER
2201	50th	REPA	RFP	NYLON	NO	NYLON	3	64 km/h (40 mph)
2202	50th	REPA	RFP	NYLON	NO	NO	3	72 km/h (45 mph)
2203	50th	REPA	RFP	6.7 (1500)	NO	NO	3	74 cm (29 in.) BELT ON SPOOL
2204	6 yr[2]	REPA	RFP	NYLON	NO	NYLON	3	20 cm (8 in.) BOLSTER
2205	50th	NO	RFP	NO	NO	NO	3	90° LATERAL* HEAD AND TORSO AIR BAGS
2206	50th	NO	RFP	NO	NO	NYLON	3	90° LATERAL HEAD AND TORSO AIR BAGS
2207	50th	NO	RFP	NO	NO	NYLON	3	90° LATERAL
2208	50th	REPA	DRIVER	NYLON	NO	NO	3	90° LATERAL
2209	50th	NO	DRIVER	NYLON	1.3 kN (300 lb) STATIC	NO	3	90° LATERAL

*ALL 90° LATERALS ARE RIGHT SIDE HITS

[1]SIERRA 492-06

[2]ALDERSON VIP-6C

Table 4.1-3
SLED AND RESTRAINT CONDITIONS

RUN NO.	VELOCITY CHANGE Km/h (mph)	ACCELERATION PEAK G_X	SLED STROKE Cm (Inches)	PULSE TIME ms	BELT ON SPOOL Cm (Inches)	SEAT POSITION
2008	53.6 (33.5)	32.2	55.4 (21.8)	81.8	101.6 (40)	MIDDLE
2009	53.8 (33.6)	32.4	56.4 (22.2)	82.6	58.4 (23)	MIDDLE
2010	53.6 (33.5)	32.1	56.1 (22.1)	82.5	129.5 (51)	MIDDLE
2011	53.8 (33.6)	32.3	56.4 (22.2)	82.5	129.5 (51)	MIDDLE
2014	53.8 (33.6)	32.5	55.9 (22.0)	82.4	129.5 (51)	MIDDLE
2015	54.1 (33.8)	33.3	55.9 (22.0)	82.1	129.5 (51)	MIDDLE
2016	53.9 (33.7)	33.7	55.9 (22.0)	82.3	129.5 (51)	MIDDLE
2017	53.9 (33.7)	33.6	N/R*	N/R	129.5 (51)	MIDDLE
2018	53.8 (33.6)	33.3	N/R	N/R	129.5 (51)	MIDDLE
2019	53.9 (33.7)	33.8	N/R	N/R	129.5 (51)	MIDDLE
2020	53.9 (33.7)	32.8	N/R	N/R	129.5 (51)	FORWARD
2021	54.1 (33.8)	33.2	N/R	N/R	129.5 (51)	FORWARD
2022	54.1 (33.8)	32.6	N/R	N/R	129.5 (51)	FORWARD
2023	54.2 (33.9)	32.7	57.4 (22.6)	83.3	129.5 (51)	FORWARD
2024	53.9 (33.7)	32.3	N/R	N/R	129.5 (51)	MIDDLE
2025	54.1 (33.8)	32.2	55.9 (22.0)	82.3	129.5 (51)	MIDDLE
2026	53.9 (33.7)	33.5	55.6 (21.9)	82.2	129.5 (51)	MIDDLE
2027	63.2 (39.5)	37.0	N/R	N/R	129.5 (51)	MIDDLE
2028	54.4 (34.0)	34.6	N/R	N/R	129.5 (51)	REAR
2029	54.6 (34.1)	34.1	N/R	N/R	129.5 (51)	REAR
2030	54.2 (33.9)	33.7	N/R	N/R	129.5 (51)	FORWARD
2031	71.4 (44.6)	40.4	84.8 (33.4)	90.2	129.5 (51)	MIDDLE
2032	71.7 (44.8)	40.2	85.8 (33.8)	89.8	N/A**	MIDDLE
2116	54.1 (33.8)	34.7	56.1 (22.1)	82.5	129.5 (51)	MIDDLE
2117	54.1 (33.8)	32.7	56.6 (22.3)	82.8	129.5 (51)	MIDDLE
2118	54.2 (33.9)	32.1	56.9 (22.4)	83.2	129.5 (51)	MIDDLE
2119	54.1 (33.8)	32.2	56.1 (22.1)	82.4	129.5 (51)	MIDDLE
2120	57.4 (35.9)	38.6	56.4 (22.2)	77.8	129.5 (51)	MIDDLE
2198	54.3 (33.8)	32.4	55.9 (22.0)	83.1	129.5 (51)	FORWARD
2199	54.1 (33.7)	31.8	55.6 (21.9)	83.0	129.5 (51)	FORWARD
2200	54.1 (33.7)	32.1	55.9 (22.0)	83.3	129.5 (51)	FORWARD
2201	62.8 (39.1)	37.5	70.1 (27.6)	86.5	129.5 (51)	MIDDLE
2202	71.3 (44.4)	41.4	N/R	N/R	129.5 (51)	MIDDLE
2203	54.0 (33.6)	32.8	N/R	N/R	73.7 (29)	MIDDLE
2204	54.0 (33.6)	31.9	N/R	N/R	129.5 (51)	FORWARD
2205	32.4 (20.2)	13.4	49.5 (19.5)	102.1	N/A	MIDDLE
2206	32.8 (20.4)	13.4	50.8 (20.0)	102.8	N/A	MIDDLE
2207	33.2 (20.7)	13.5	53.6 (21.1)	102.4	N/A	MIDDLE
2208	34.0 (21.2)	13.5	51.3 (20.2)	102.6	129.5 (51)	MIDDLE
2209	33.6 (20.9)	13.3	52.1 (20.5)	103.9	N/A	MIDDLE

*N/R = Not Recorded
**N/A = Not Applicable

Table 4.1-4
RESTRAINT DATA

RUN NO.	POSITION	WEBBING kN (lbs)	PRE-LOADER	BELT LOAD CELLS* kN (lbs)				
				NO. 1	NO. 2	NO. 3	NO. 4	NO. 5
2008	RFP	POLYESTER	NONE	N/A	10.9 (2450)	8.2 (1850)	N/A	N/A
2009**	RFP	POLYESTER	NONE	N/M	9.3 (2100)	6.4 (1450)	N/A	N/A
2010	RFP	NYLON	REPA	10.2 (2300)	9.1 (2050)	7.1 (1600)	N/A	N/A
2011	RFP	NYLON	NONE	7.0 (1575)	9.3 (2100)	6.6 (1500)	N/A	N/A
2014	RFP	6.67 (1500)	REPA	4.6 (1050)	6.2 (1400)	6.6 (1500)	N/A	N/A
2015	RFP	6.67 (1500)	REPA	3.3 (750)	6.2 (1400)	LOST	N/A	N/A
2016	RFP	4.44 (1000)	REPA	8.8 (2000)	7.7 (1750)	4.0 (900)	N/A	N/A
2017	RFP	6.67 (1500)	REPA	3.7 (850)	5.7 (1300)	5.1 (1150)	N/A	N/A
2018	RFP	6.67 (1500)	REPA	N/M	6.0 (1350)	4.8 (1100)	N/M	2.22 (500)
2019	RFP	6.67 (1500)	NONE	5.6 (1250)	5.6 (1250)	4.8 (1100)	N/A	N/A
2020	RFP	POLYESTER	NONE	6.6 (1500)	9.1 (2050)	8.2 (1850)	N/A	N/A
2021	RFP	6.67 (1500)	REPA	6.0 (1350)	5.5 (1250)	4.4 (1000)	N/A	N/A
2022	RFP	POLYESTER	NONE	4.6 (1050)	6.6 (1500)	5.1 (1150)	N/A	N/A
2023	RFP	6.67 (1500)	REPA	N/M	5.5 (1250)	4.4 (1000)	2.22 (500)	N/M
2024	RFP	POLYESTER	NONE	8.1 (1825)	11.5 (2600)	9.5 (2150)	N/A	N/A
2025	RFP	NYLON	NONE	6.3 (1420)	8.8 (2000)	8.2 (1850)	N/A	N/A
2026	RFP	4.44 (1000)	FFV	1.4 (325)	5.7 (1300)	4.6 (1050)	N/A	N/A
2027	RFP	6.67 (1500)	REPA	4.4 (1000)	6.6 (1500)	5.3 (1200)	N/A	N/A
2028	RFP	NYLON	REPA	8.0 (1800)	9.3 (2100)	8.0 (1800)	N/A	N/A
2029	RFP	6.67 (1500)	REPA	5.1 (1150)	7.7 (1750)	5.5 (1250)	N/A	N/A
2030	RFP	POLYESTER	NONE	N/M	4.6 (1050)	5.2 (1175)	N/A	N/A
2031	RFP	6.67 (1500)	REPA	4.2 (950)	6.0 (1350)	5.1 (1150)	N/A	N/A
2032	RFP	6.67 (1500)	1.3 kN (300 lb)***	5.5 (1250)	7.3 (1650)	5.1 (1150)	N/A	N/A
2116	RFP	NYLON	NONE	11.6 (2600)	10.5 (2350)	8.7 (1950)	N/A	N/A
2117	RFP	6.67 (1500)	REPA	4.0 (900)	7.3 (1350)	6.9 (1550)	N/A	N/A
2118	DRIVER	6.67 (1500)	REPA	4.1 (925)	6.3 (1425)	6.2 (1400)	N/A	N/A
2119	DRIVER	NYLON	NONE	6.2 (1400)	9.2 (2075)	7.5 (1675)	N/A	N/A
2120	DRIVER	6.67 (1500)	REPA	3.6 (820)	6.2 (1400)	6.5 (1450)	N/A	N/A
2120	RFP	6.67 (1500)	REPA	3.6 (820)	6.6 (1490)	6.0 (1350)	N/A	N/A
2198	RFP	NYLON	NO	3.6 (820)	5.3 (1200)	3.7 (830)	N/M	3.5 (790)
2199	RFP	NYLON	NO	3.6 (820)	5.2 (1160)	3.6 (800)	N/M	5.0 (1120)
2200	RFP	NYLON	NO	N/M	5.7 (1280)	4.5 (1000)	2.7 (610)	2.2 (500)
2201	RFP	NYLON	NO	7.8 (1750)	10.5 (2350)	9.0 (2020)	N/A	N/A
2202**	RFP	NYLON	NO	13.7 (3100)	10.0 (2250)	10.9 (2440)	N/A	N/A
2203	RFP	6.67 (1500)	NO	4.9 (1100)	6.5 (1400)	6.1 (1370)	N/A	N/A
2204	RFP	NYLON	NO	N/M	3.3 (750)	2.3 (520)	3.2 (710)	2.8 (620)
2205	RFP	NO	NO	N/A	N/A	N/A	N/A	N/A
2206	RFP	NO	NO	N/A	N/A	N/A	N/M	N/M
2207	RFP	NO	NO	N/A	N/A	N/A	N/M	N/M
2208	DRIVER	NYLON	NO	4.0 (910)	5.4 (1210)	3.6 (820)	N/A	N/A
2209	DRIVER	NYLON	1.3 kN (300 lb)***	5.0 (1120)	7.1 (1600)	10.5 (2350)	N/A	N/A

*NO. 1 - BETWEEN ELR AND D-RING
NO. 2 - UPPER TORSO BELT
NO. 3 - LOWER TORSO BELT
NO. 4 - LEFT LAP
NO. 5 - RIGHT LAP
**BELT RIPPED AT D-RING
***STATIC

These data demonstrate (Table No. 4.1-1) that for the 50th percentile male ATD, FMVSS 208 performance evaluation criteria are met at 55 Km/h (34 MPH) sled velocity change with all of the restraint system configurations (Table No. 4.1-2) tested on both the right front passenger and the driver. At a sled velocity change of 64 Km/h (40 MPH) FMVSS 208 criteria are met by the 50th percentile ATD right front passenger in both the baseline system and the pre-loaded force limiting system. The driver position was not tested at this velocity. Two preloading configurations (one dynamic and one static) of the force limiting belt system were tested at 72 Km/h (45 MPH) and the 50th percentile ATD right front passenger met the applicable criteria. When the baseline system (no preloading nor force limiting) was tested at this velocity the torso belt webbing failed at the upper D-ring and the 50th percentile ATD exceeded the upper limits of FMVSS 208 criteria in both the HIC value and chest resultant acceleration.

One test of the full system was conducted at a sled velocity change of 58 km/hr (36 MPH) using two 50th percentile ATDs as the driver and right front passenger. The purpose of this test (run no. 2120) was to determine if there would be any adverse interplay between the ATDs. There was no ATD to ATD contact during the test and, while the right front passenger results met the performance criteria, the driver chest resultant acceleration exceeded the 60 G limit.

A 5th percentile female ATD as the right front passenger was tested in the baseline configuration and the full system (run nos. 2020 and 2021) at 55 km/hr (34 MPH). Electrical noise overriding the data traces prevented determination of the HIC and chest severity index (CSI) values. However it is assumed that the HIC would have met the criteria limits in both tests. The chest resultant acceleration for the baseline test was 60 G and for the force limited system it was 40 G. The head resultant accelerations were 140 G and 54 G, respectively.

Run nos. 2028 and 2029 were baseline and force limiting system tests at sled velocities of 55 km/hr (34 MPH) utilizing 95th percentile ATDs as the right front passenger. The baseline system provided a HIC value of 1080 (above the criteria limit) while the preloaded force limiting system produced a HIC value of 292 (well below the criteria limit). Chest resultant accelerations were within the criteria limits for both tests. Six tests (2022, 2030, 2198, 2199, 2200 and 2204) were conducted using six year old size ATDs. The first five tests were conducted with a Sierra 492-06 ATD and the sixth with an Alderson VIP-6C ATD. Tests nos. 2200 and 2204 were replicate tests with regard to sled conditions and restraint configuration. The primary findings from these two tests in which the results from one ATD (the Sierra) exceeded FMVSS 208 criteria and the other ATD (the Alderson) did not, is that there exists considerable variability between the two ATDs both in anthropometry and in kinematics under the same test conditions. The results of these 6 year old tests will be discussed further in Section 5 of this report.

4.2 CVS Computer Simulations

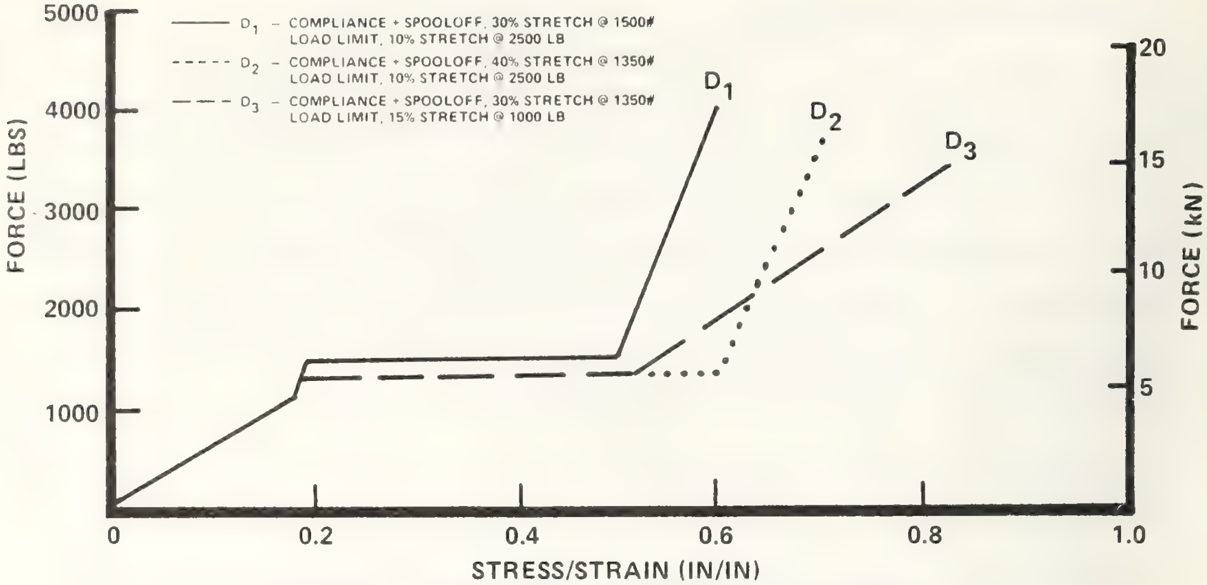
The objectives of the final phase of the computer simulation study (Task 4) were threefold: (1) to create a data base comprised of selected simulations closely aligned with sled occupant response data; (2) to use this data base in a predictive mode to determine occupant performance trends as a function of changes in velocity, ATD size and impact angle; and (3) to store this data as input parameters and output data at the Edgewood, Maryland computer facility for ease of access by the NHTSA.

1) Creation of a Data Base

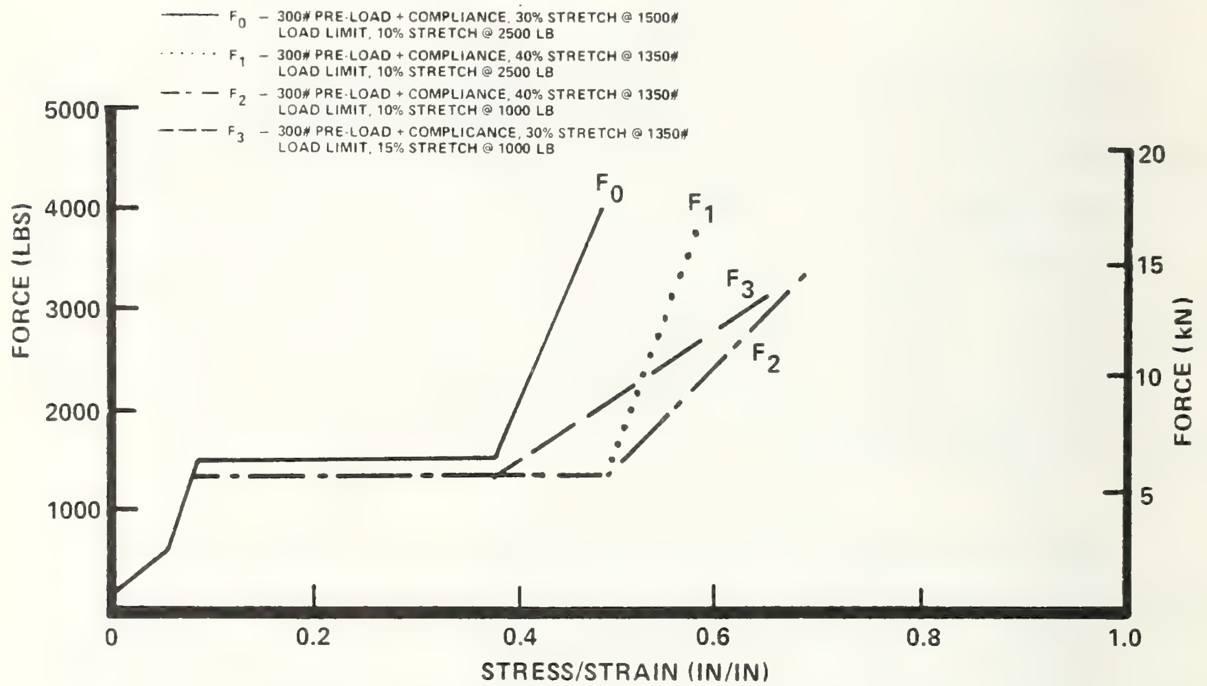
As in Task 2, the nine simulations which incorporated all the belt configurations used during sled testing were considered the data base to be aligned with sled data.

At the completion of Task 2, the developmental phase of the computer simulation study, the input parameters for vehicle interior geometry, ATD characteristics, vehicle plane force-deflection functions and sled pulse wave forms had been determined. The purpose of Task 4 was to further refine the dynamic belt force-deflection functions and to analyze the resulting occupant responses. The belt force-deflection input curves actually simulate mutual ATD/belt effective interaction characteristics. Thus, the belt curves generated include dynamic spool-off, dummy compliance, effective force-limiting levels and effective webbing elongation.

Refinement of the mutual dynamic ATD/belt force-deflection characteristics was accomplished in a progressive manner. The simulations used for tailoring the belt characteristics were runs 2017 and 2032, a 34 MPH and a 45 MPH simulation, respectively. As demonstrated in Figure 4.2-1, several different levels of force-limiting, force-limiting elongation and nylon elongation were attempted and output comparisons were made at both velocity



CURVE D – 1500# FORCE LIMITING, PRE-LOADED



CURVE F – 1500# LOAD LIMIT, 300# STATIC PRE-LOAD

Figure 4.2-1 BELT/ATD MUTUAL FORCE-DEFLECTION CHARACTERISTIC TAILORING

levels. When a compromise was reached on the most reasonable effect of the belt curve on occupant response for these two runs, belt characteristics were input, where applicable, to the other simulations in the data base. When significant discrepancies were noticed in output response comparisons more changes were made to the belt curves.

The final belt stress/strain curves used for data base simulations are displayed in Figures 4.2-2 through 4.2-7. The rationale for the creation of these belt force deflection curves is as follows:

Spool-off measured on the available sled data was incorporated into the early slope of the belt curves, along with measured dummy compliance (Reference 6). As the curves indicate, 1500 lb. and 1000 lb. force-limiting webbing, when faired through the oscillations found on sled data traces, effectively force-limit at 1350 lbs. with 30 percent elongation and 900 lbs. with 20 percent elongation, respectively. When the force-limiting elongation has been expended the belt stress/strain properties revert to nylon webbing characteristics. Since the current CVS III belt algorithm does not allow belt slippage, contact with more than one ellipsoid or more than one user-specified friction (spike) option the effective nylon stress/strain curve must include such things as the results of dummy spin-off and belt slippage.

The sensitivity of the belt force-deflection function input curve is illustrated in Figures 4.2-8 and 4.2-9. The CVS baseline simulation contained four inches of dynamic-spool off in the belt curve. Figure 4.2-8 is a simulation/sled comparison plot of the CVS baseline simulation and a baseline sled run having a measured spool-off of four inches. Chest resultant acceleration and shoulder belt load data traces correlate well in both pulse shape and peak values. Figure 4.2-9 shows a simulation/sled comparison plot of the same CVS baseline simulation and a baseline sled run having a measured spool-off of eight inches. The greater amount of spool-off in this sled run causes both the shoulder belt load and the chest resultant acceleration data traces to rise later and peak higher than is seen in the simulation. In order to be used in a predictive mode, the CVS input parameters must be defined as precisely as possible.

Figure 4.2-2 CURVE A – NYLON WEBBING

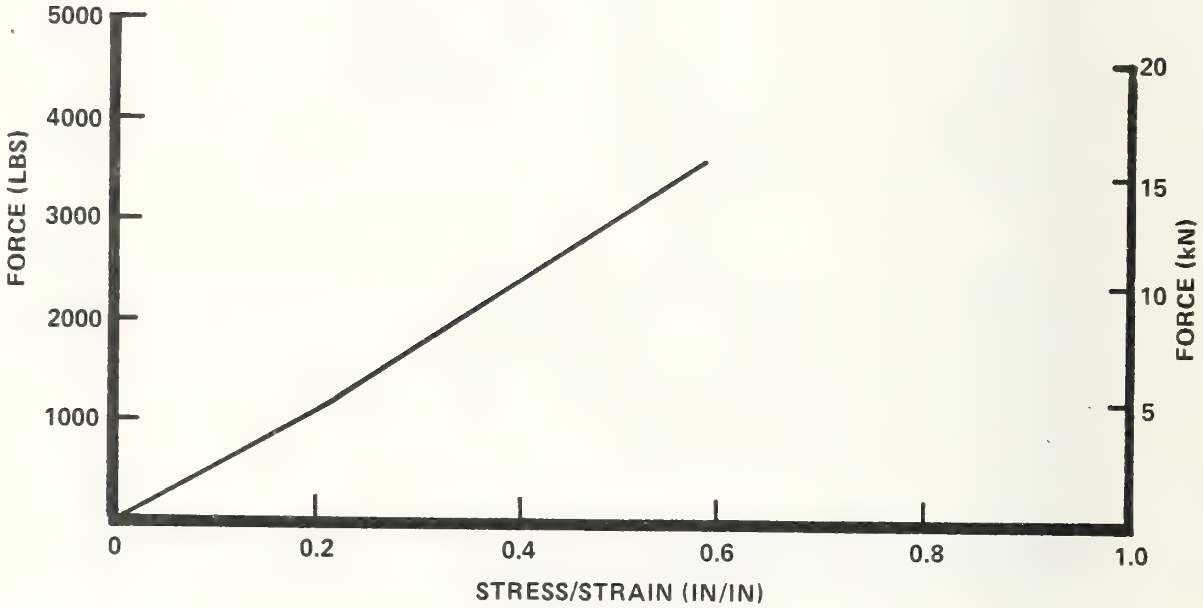


Figure 4.2-3 CURVE B – NYLON WEBBING, PRE-LOADED

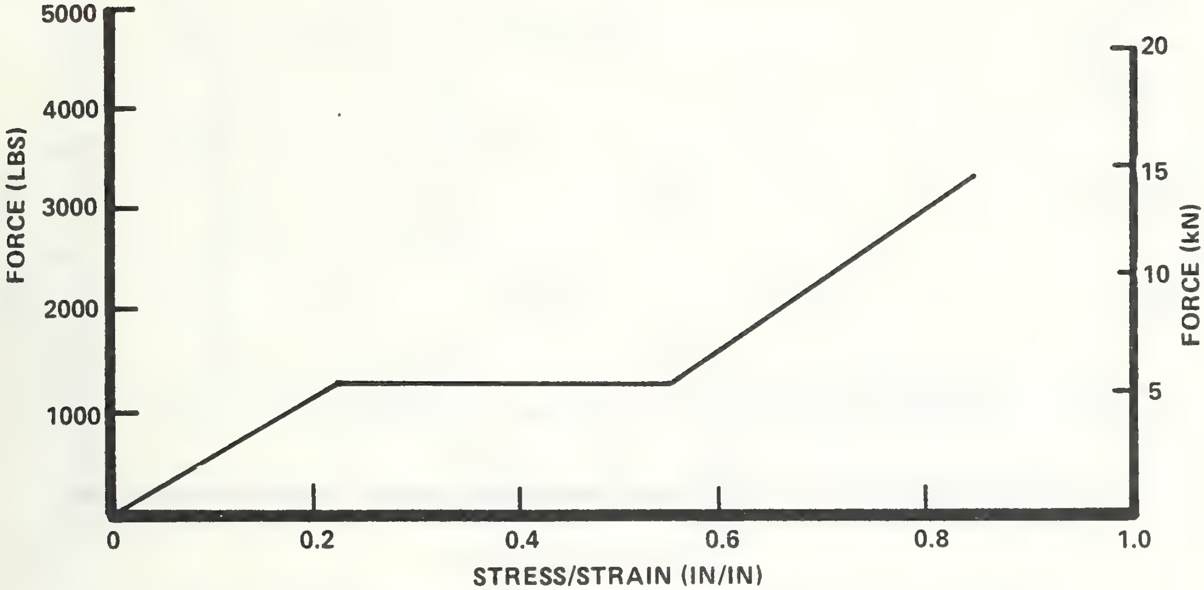


Figure 4.2-4 CURVE C – 1500# FORCE LIMITING, NO PRE-LOAD

Figure 4.2-5 CURVE D – 1500# FORCE LIMITING, PRE-LOADED

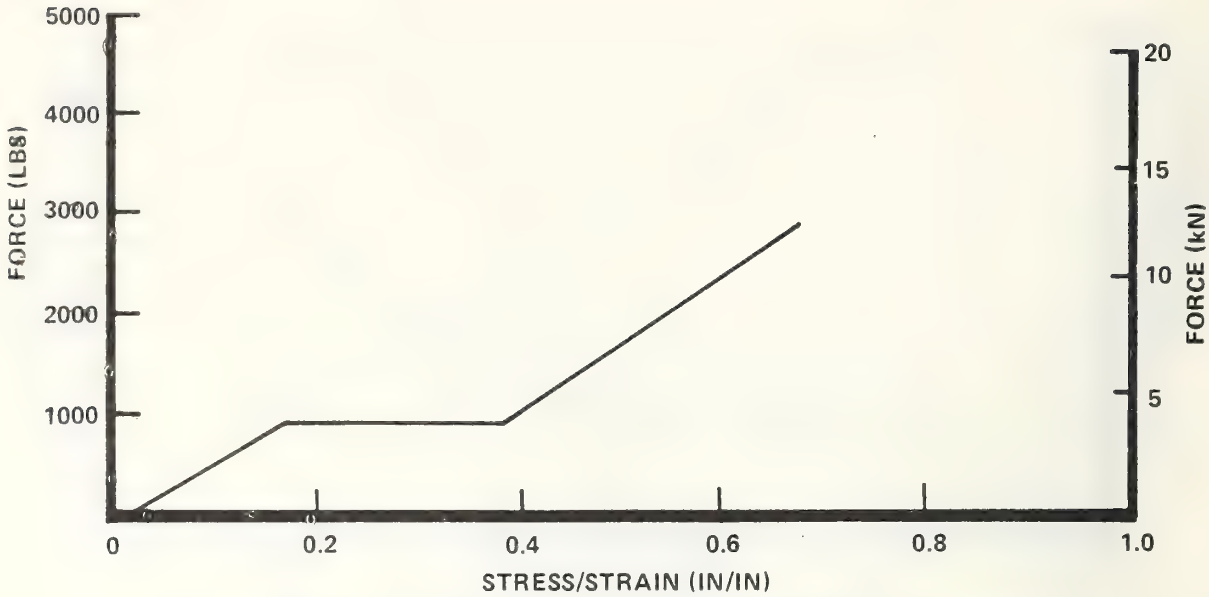


Figure 4.2-6 CURVE E – 1000# FORCE LIMITING, PRE-LOADED

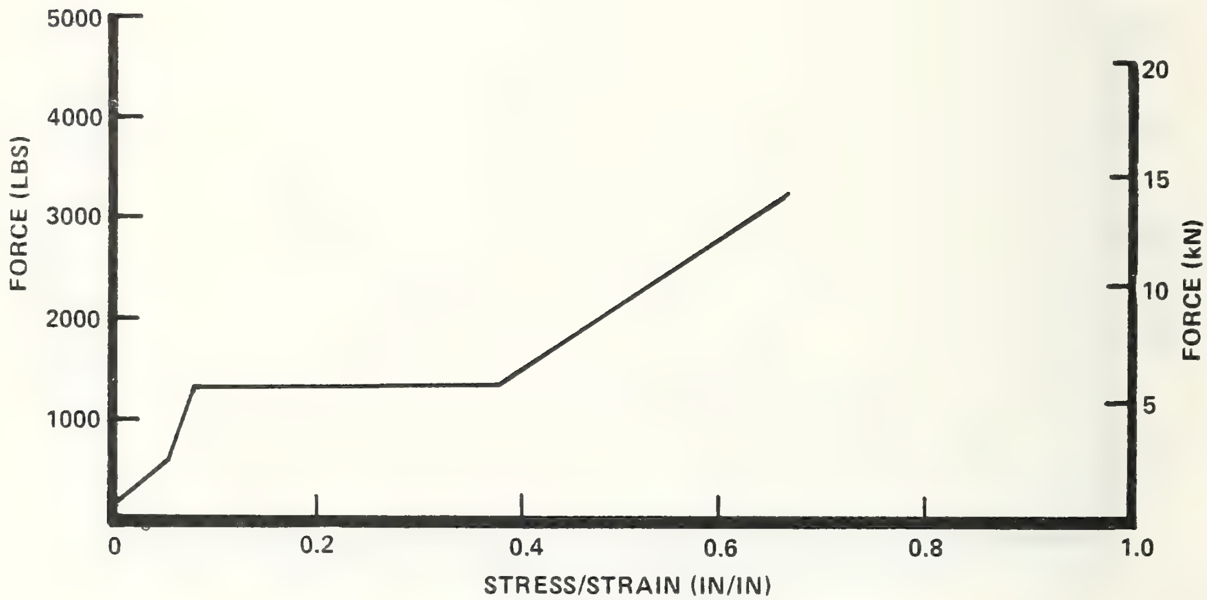
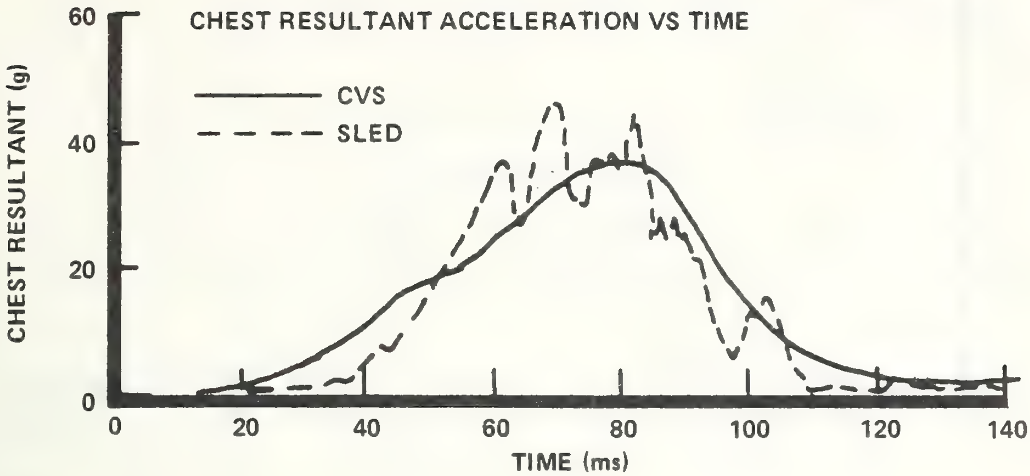


Figure 4.2-7 CURVE F – 1500# FORCE LIMITING, 300# STATIC PRE-LOAD



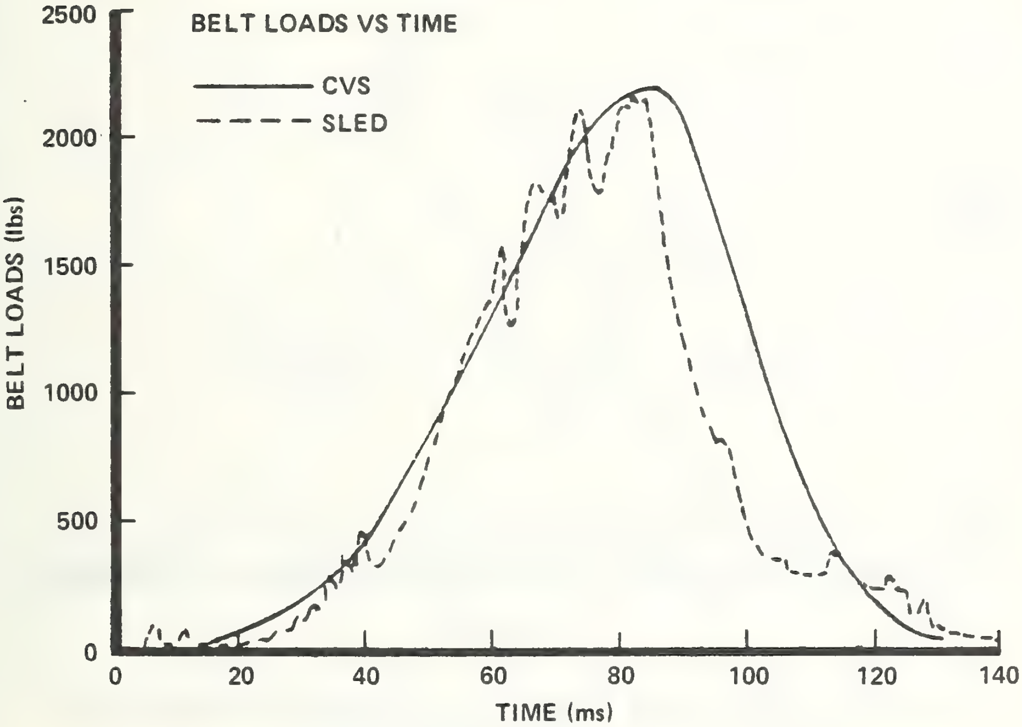


Figure 4.2-8 BELT FORCE – DEFLECTION FUNCTION SENSITIVITY
SLED DATA – 4 INCHES SPOOL OFF
SIMULATION DATA – 4 INCHES SPOOL OFF

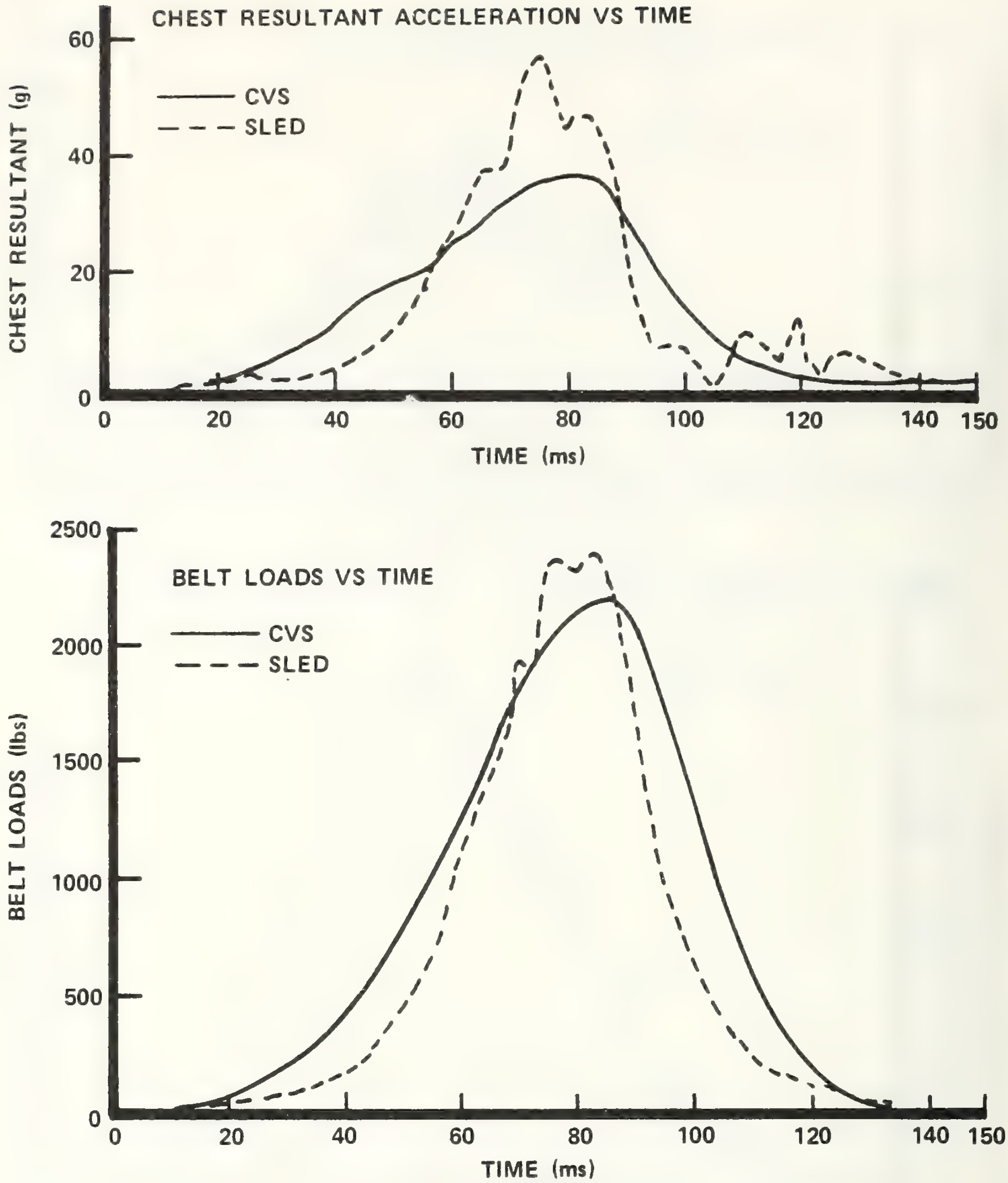


Figure 4.2-9 BELT FORCE – DEFLECTION FUNCTION SENSITIVITY
SLED DATA – 8 INCHES SPOOLOFF
SIMULATION DATA – 4 INCHES SPOOL OFF

Because the shoulder belt load is more critical in terms of dummy kinematics and chest loads than the lower belt loads it was used as a criterion for correlating data base simulation and sled data. However, it should be noted that the present belt algorithm contains a friction option which causes the belt to be 'spiked' at a predetermined location on the contact ellipsoid causing the belt loads to differ at the upper and lower anchor points. When this option is not used the upper and lower anchor point belt loads have identical values. Data measured from load cells located near the upper and lower anchor points on the torso belt during sled runs indicates higher readings at the shoulder and therefore this 'spike' option was used throughout the computer simulations. These belt loads are illustrated in Figure 4.2-10.

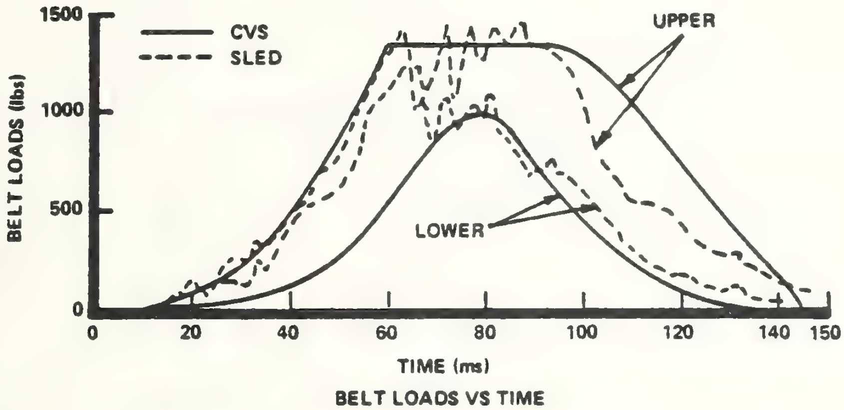


Figure 4.2-10 SIMULATION/SLED COMPARISON BELT LOADS USING BELT FULL FRICTION OPTION

Comparisons of sled/simulation data for the nine data base runs are displayed in Appendix B, pages B-1 through B-45.

2) Predictive Mode

This computer simulation study requires very specialized input information, some of which has been determined in an experimental manner. In the predictive mode, the CVS III program is most reliable when the variable on which the prediction is based has been closely aligned with actual sled data. The data base simulations, having demonstrated an acceptable level of occupant response data correlation with sled tests, were selectively used in a predictive manner.

The most reliable simulation predictions were generated when the variable was the sled velocity and the belt force deflection characteristics.

- Sled velocity change was input to the program as acceleration time history information taken at 5 msec. intervals from sled pulse checks at the velocities to be investigated. Figures 4.2-11a and 4.2-12a show simulation data traces indicating a trend toward higher shoulder belt loads and higher peak head resultant acceleration levels, respectively, as a function of increased velocity. Subsequent to these simulation runs, the sled runs were made at these velocities and Figures 4.2-11b and 4.2-12b indicate the same trend in the sled data traces.

- Belt force deflection functions had undergone extensive experimental refinements, as was discussed previously. The simulation data in Figure 4.2-13a and 4.2-14a indicate that the 'full system' (i.e., 1500 lb. force limited webbing, preloaded) belt causes lower head and chest resultant acceleration peak values than the baseline system (i.e., nylon webbing). Again, the sled test data traces agree with the trends predicted by the simulations (Figures 4.2-13b and 4.2-14b).

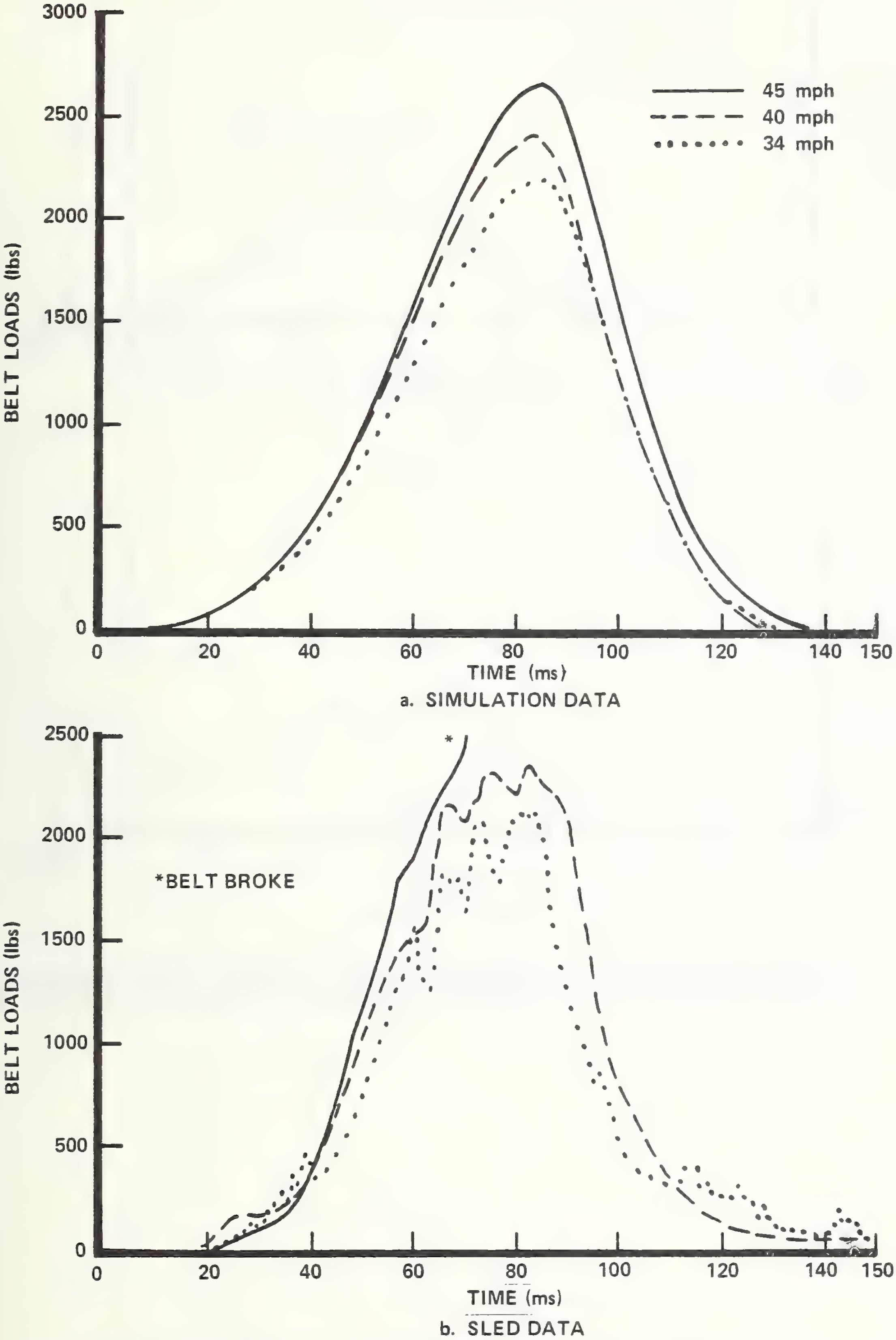


Figure 4.2-11 SIMULATION/SLED COMPARISON DATA AT VELOCITIES OF 34, 40 AND 45 MPH RUNS 2011, 2201, 2202 BASELINE, SHOULDER BELT LOADS VS TIME

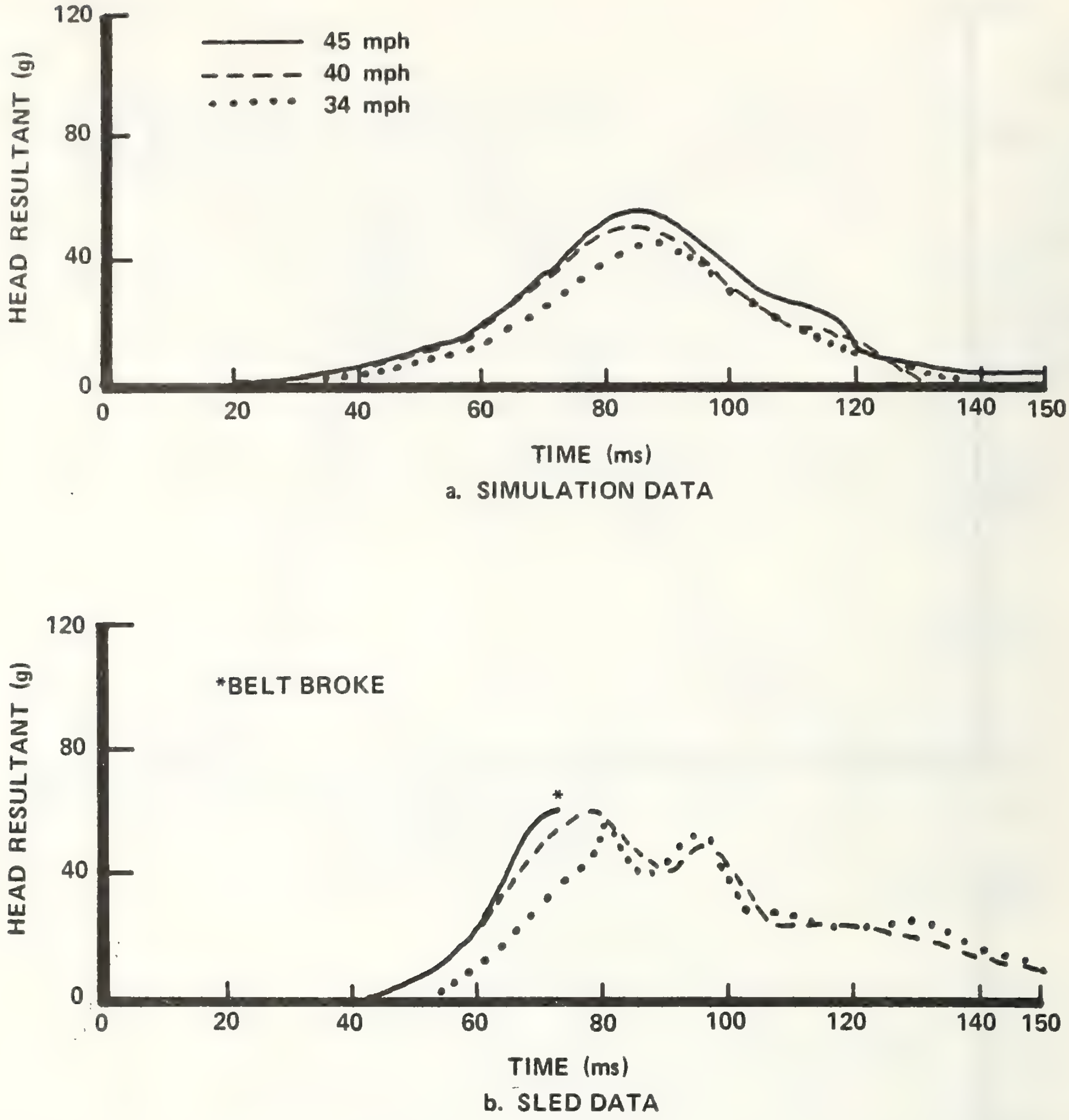
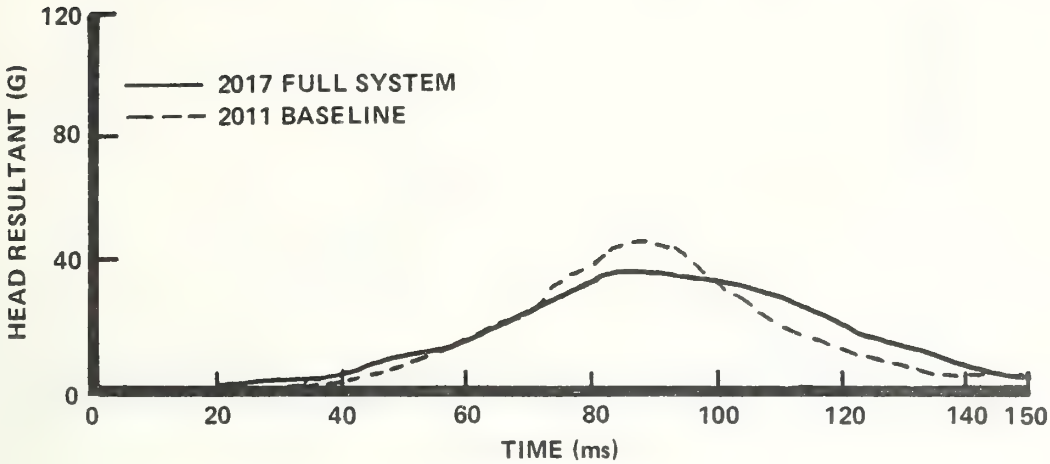
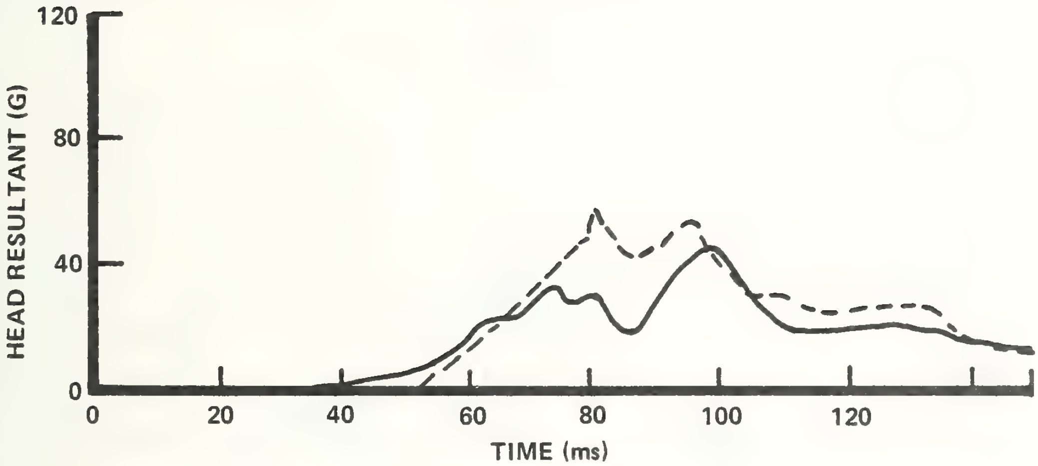


Figure 4.2-12 SIMULATION/SLED COMPARISON DATA AT VELOCITIES OF 34, 40 AND 45 MPH RUNS 2011, 2201, 2202 BASELINE, HEAD RESULTANT ACCELERATION VS TIME

HEAD RESULTANT ACCELERATION vs. TIME



a. SIMULATION DATA



b. SLED DATA

Figure 4.2-13 COMPARISON OF BASELINE AND FULL SYSTEM BELT CONFIGURATION HEAD RESULTANT DATA 34 MPH

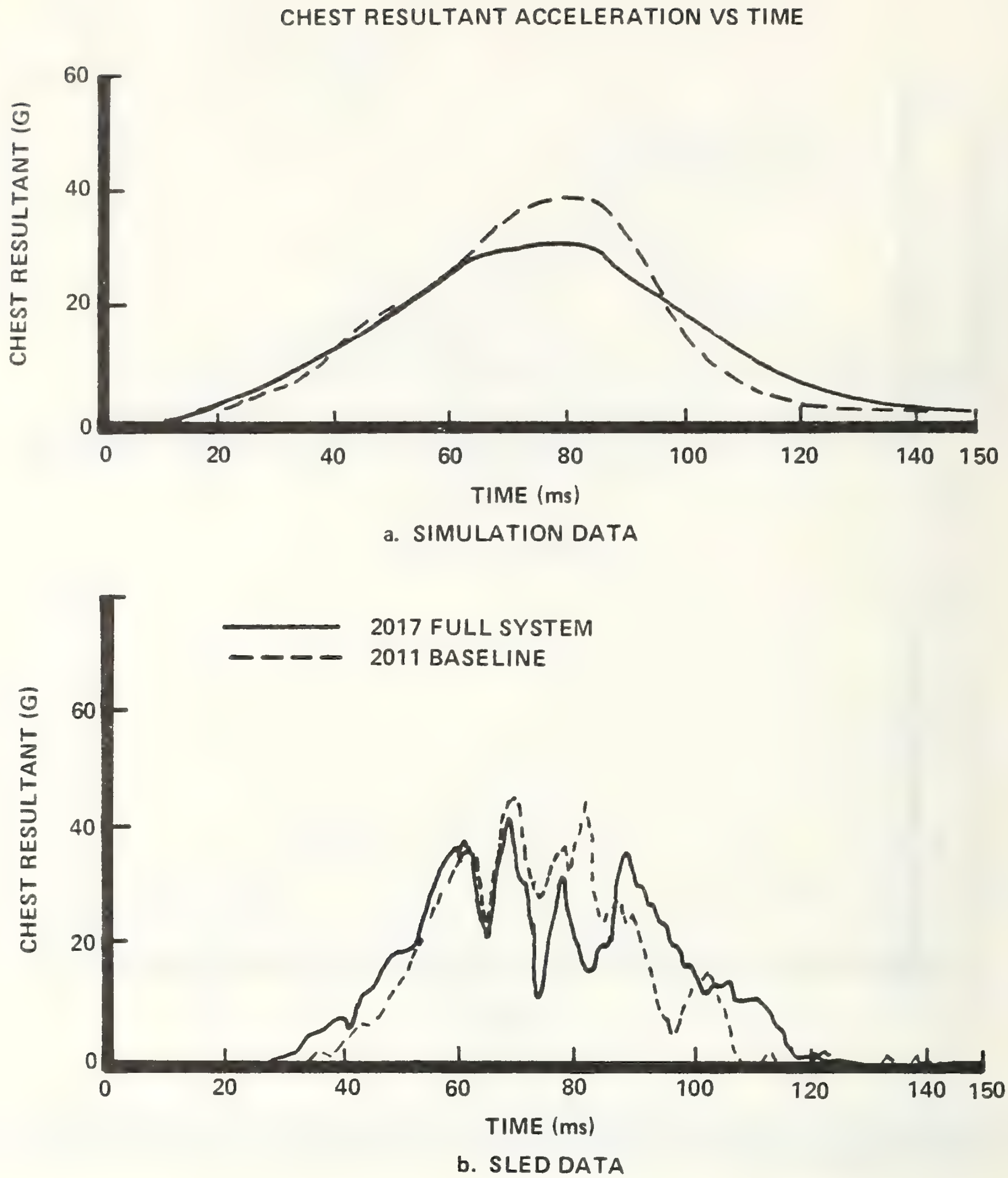


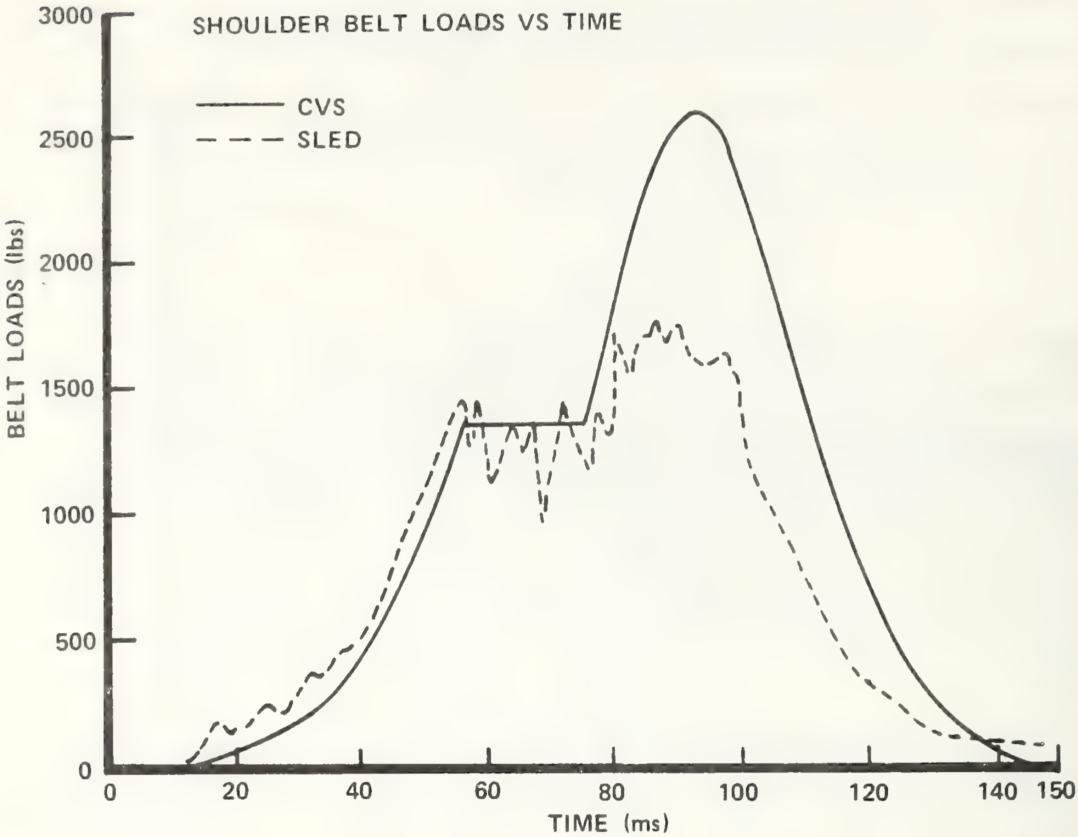
Figure 4.2-14 COMPARISON OF BASELINE AND FULL SYSTEM BELT CONFIGURATION CHEST RESULTANT DATA 34 MPH

In addition to the requirement for very specialized input information, CVS III also requires that existing program algorithms be applicable. When predictive simulations were attempted using other than the 50th percentile ATD model, positioning the occupant as the driver and at impact angles other than zero degrees, the output data did not demonstrate a reliable predictive capability.

- Figure 4.2-15 illustrates shoulder belt load and head excursion sled/simulation comparisons of the 95th percentile right front passenger. It was determined that the available 95th percentile ATD model input was not patterned on an actual 95th percentile dummy and therefore meaningful kinematic data could not be expected. It was decided, in consultation with the CTM that simulations would not be attempted with the off-size models, although the data on the 95th percentile has been saved and stored at the Edgewood facility.

- Two simulations of the 50th percentile driver, with the steering column input as different sized planes, are shown in Figures 4.2-16 and 4.2-17. It is believed that with the trial and error method of simulation effort, as described previously in respect to determining belt force-deflection characteristics, a representative steering column force-deflection curve could eventually be generated.

- At angles other than zero degrees, belt algorithm problems are encountered and dummy kinematics differ significantly from actual sled runs. Figure 4.2-18 demonstrates this problem when lateral simulations are attempted. The shoulder belt, not being allowed by the belt algorithm to slide, generates much higher loads than are actually experienced in a sled run. Two predictive oblique simulations were generated at 14 degrees and 30 degrees (R14DEG and R30DEG).



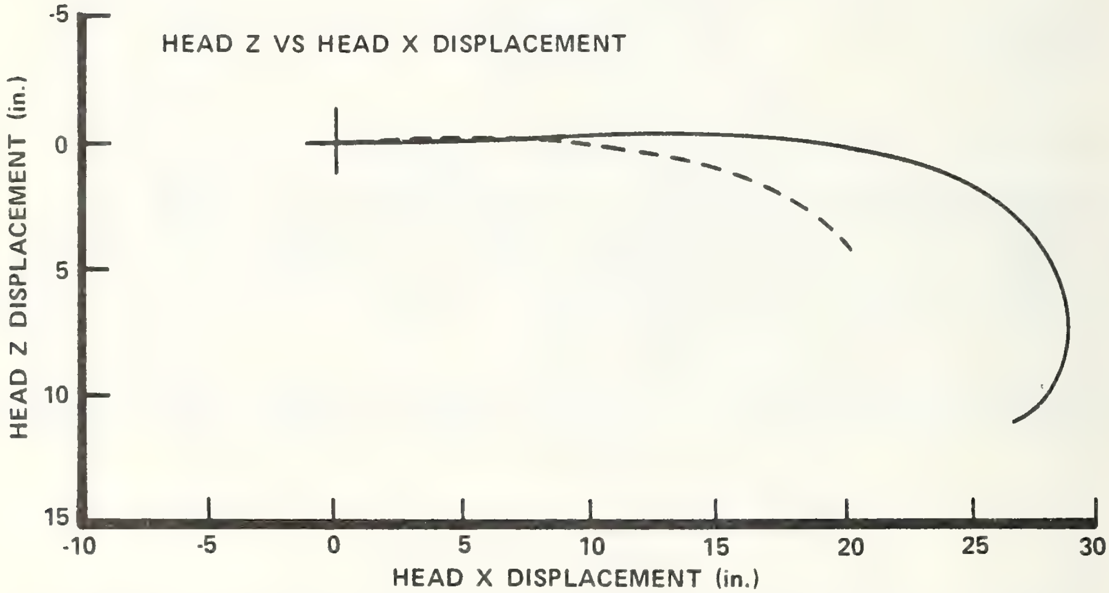
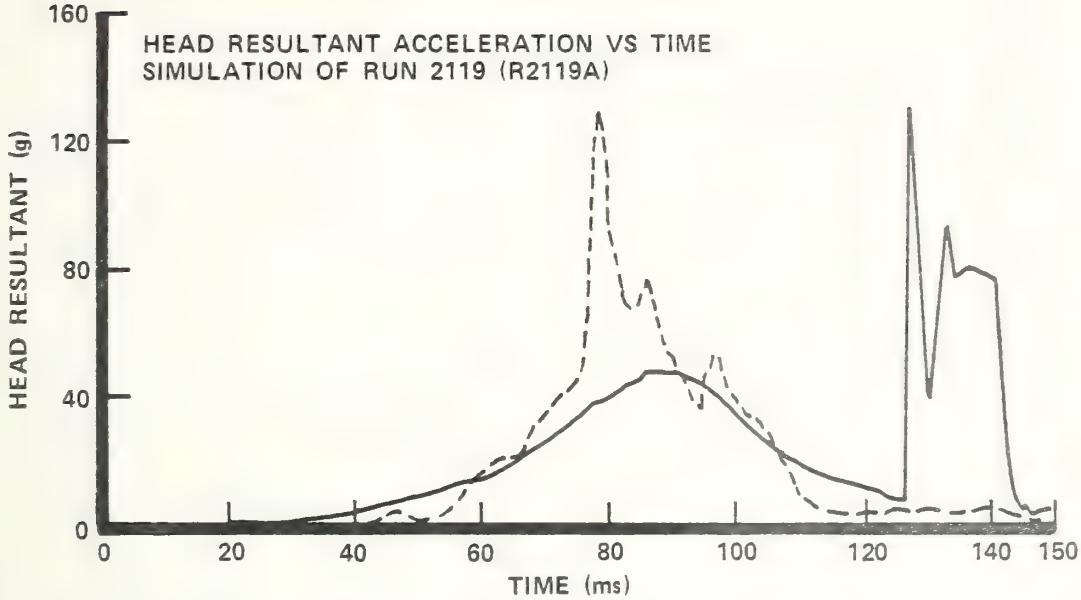


Figure 4.2-15 SIMULATION/SLED COMPARISON RUN 2029 FULL SYSTEM – 95th PERCENTILE RFP



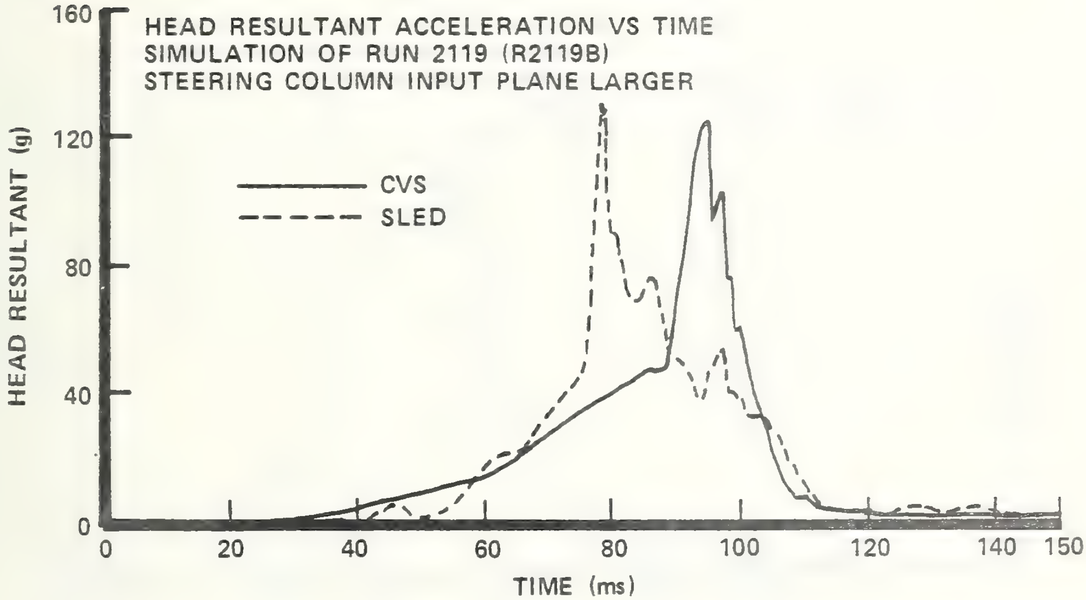
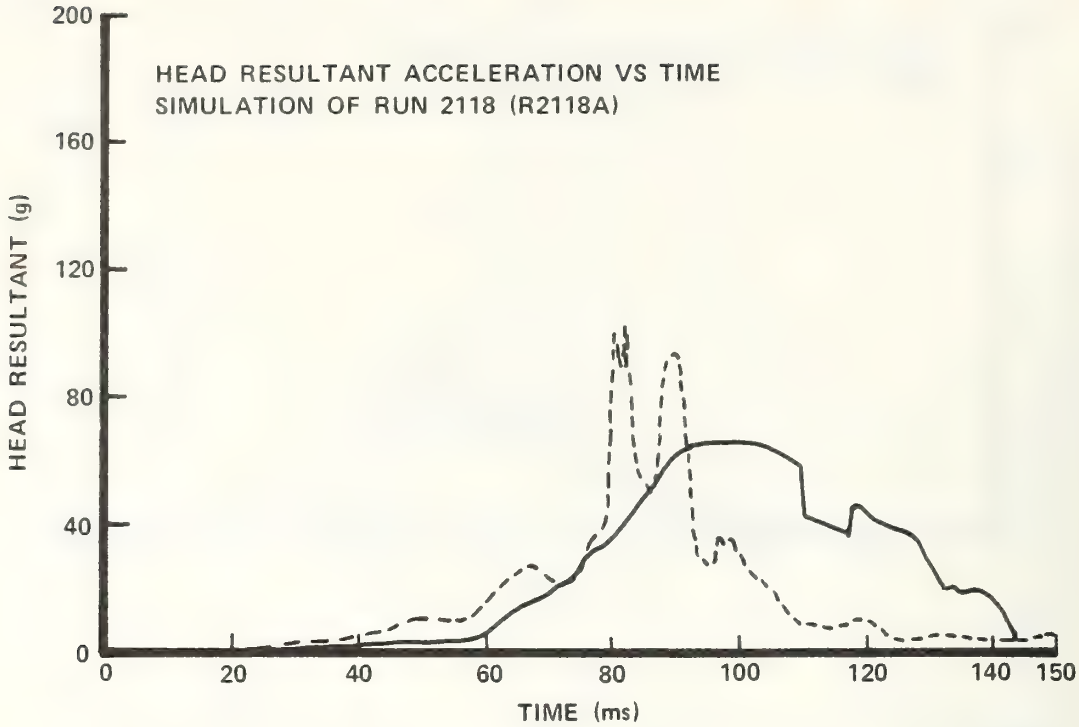


Figure 4.2-16 SIMULATION/SLED COMPARISON RUN 2119 DRIVER-BASELINE



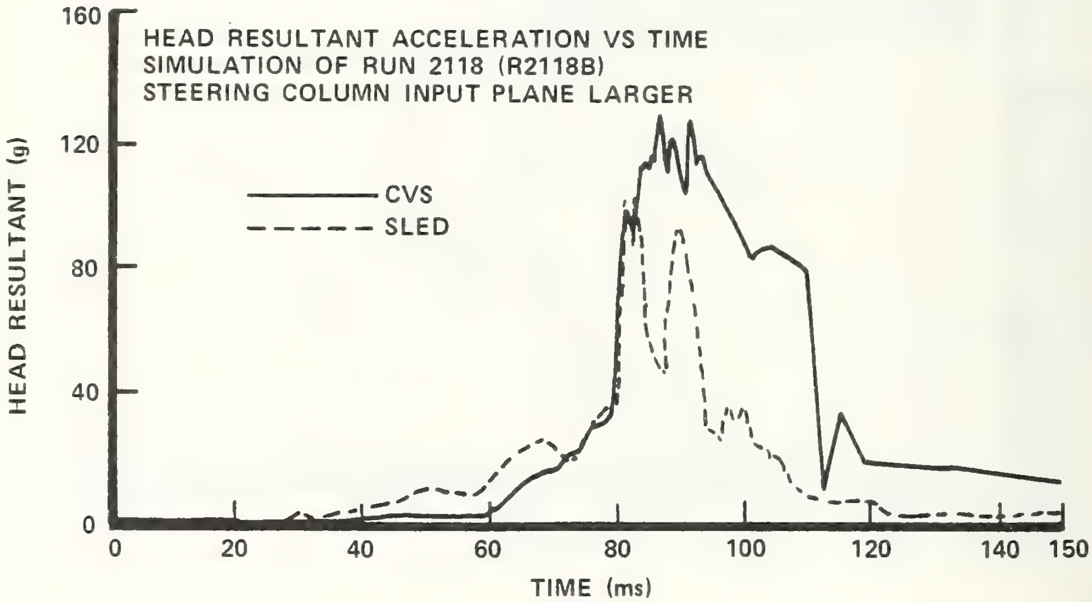
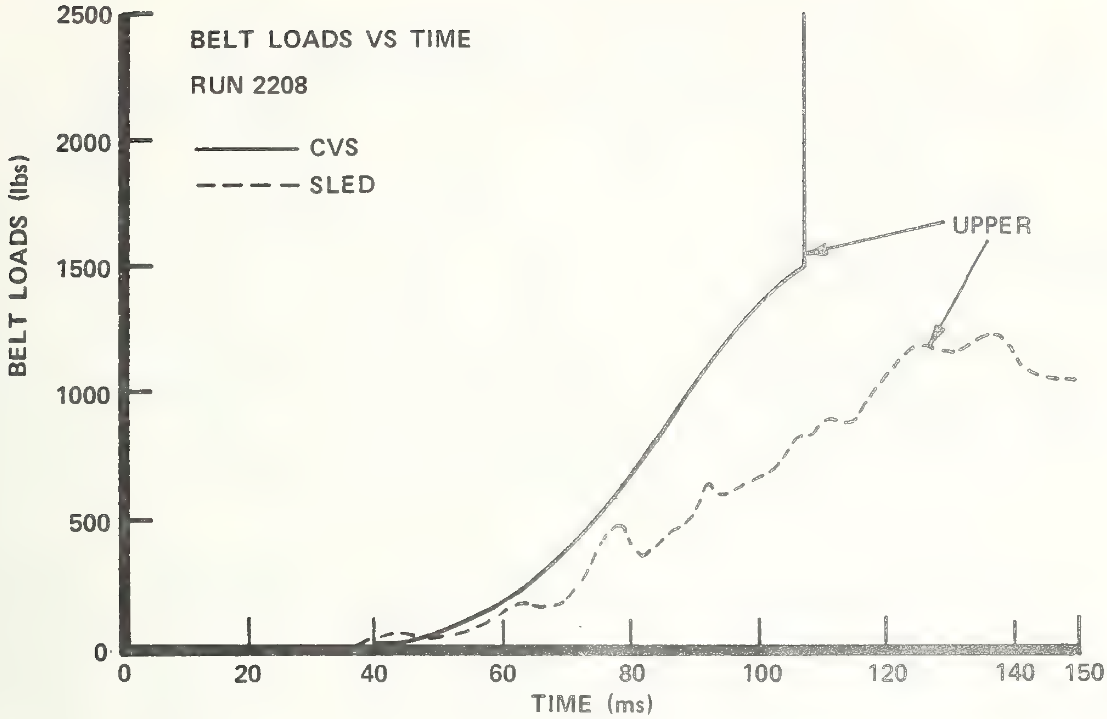


Figure 4.2-17 SIMULATION/SLED COMPARISON RUN 2118 DRIVER-FULL SYSTEM



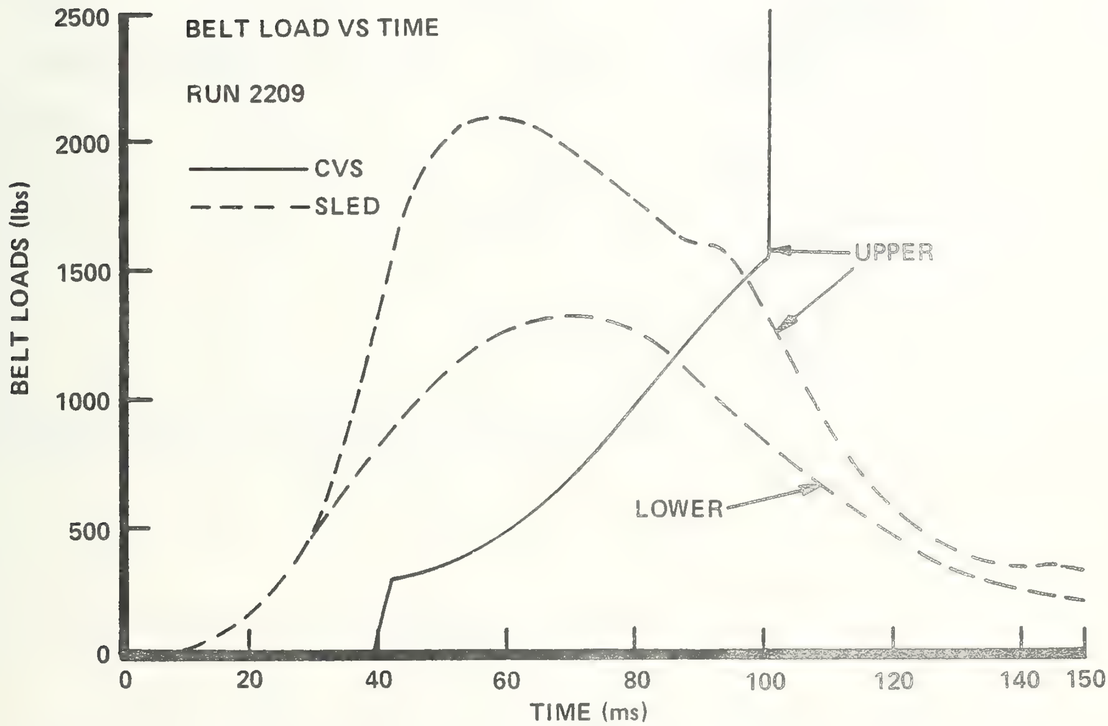


Figure 4.2-18 90° LATERAL BELT LOAD SIMULATION/SLED COMPARISON

All the simulation data traces including the lateral and oblique simulations, are found in Appendix B. Where applicable, these data traces are overlayed with sled test measurements. Table 4.2-1 contains pertinent data on all Task 4 simulations.

3) Data Storage

The naming convention for stored input and output described in Section 3.2 was adhered to in all cases except R14DEG and R30DEG which were predictive 14 degree and 30 degree oblique sled test simulations. There were no oblique sled tests to compare to these simulations.

All task 4 data is stored at the Edgewood, Maryland facility on tape 2338P4, and the input and output identification are found on Table 4.2-2. The first file consists of 19 elements of input which can be accessed to create the output data found in files 2 through 20 or can be modified by a user to output new simulations. Files 2 through 20 are packed binary files of output data. Appendix B contains a brief description of the current Univac 1108 command language used to access the stored simulation data.

Table 4.2-1

CVS III SIMULATIONS

CVS III RUN NO.	SIMULATION OF SLED RUN NO.	VELOCITY Km/h (mph)	ATD	POSITION	BELT F-D CURVE	DESCRIPTION
R2011	2011	55 (34)	50	RFP	A	BASELINE PASSIVE SYSTEM
R2010	2010	55 (34)	50	RFP	B	PASSIVE SYSTEM WITH PRELOADING
R2019	2019	55 (34)	50	RFP	C	PASSIVE SYSTEM WITH LOAD-LIMITING
R2017	2017	55 (34)	50	RFP	D	PASSIVE SYSTEM WITH PRELOADING AND LOAD-LIMITING
R2018	2018	55 (34)	50	RFP	D, G	PASSIVE SYSTEM WITH PRELOADING, LOAD-LIMITING AND ACTIVE LAP BELT
R2201	2201	64 (40)	50	RFP	A	BASELINE PASSIVE SYSTEM
R2027	2027	64 (40)	50	RFP	D	PASSIVE SYSTEM WITH PRELOADING AND LOAD-LIMITING
R2202	2202	72 (45)	50	RFP	A	BASELINE PASSIVE SYSTEM
R2031	2031	72 (45)	50	RFP	D	PASSIVE SYSTEM WITH PRELOADING AND LOAD-LIMITING
R2119	2119	55 (34)	50	DRIVER	A	BASELINE PASSIVE SYSTEM
R2118	2118	55 (34)	50	DRIVER	D	PASSIVE SYSTEM WITH PRELOADING AND LOAD LIMITING
R2028	2028	55 (34)	95	RFP	A	BASELINE PASSIVE SYSTEM
R2029	2029	55 (34)	95	RFP	D	PASSIVE SYSTEM WITH PRELOADING AND LOAD-LIMITING
R2016	2016	55 (34)	50	RFP	E	PASSIVE SYSTEM WITH PRELOADING AND LOAD-LIMITING*
R2032	2032	72 (45)	50	RFP	F	PASSIVE SYSTEM WITH STATIC PRELOAD AND LOAD LIMITING
R2208	2208	32 (20)	50	DRIVER	A	90° LATERAL, BASELINE
R2209	2209	32 (20)	50	DRIVER	F	90° LATERAL, FORCE LIMITING WEBBING, 300 # STATIC PRE-LOAD
R14DEG	–	55 (34)	50	RFP	D	14° OBLIQUE, FORCE LIMITED AND PRELOADED
R30DEG	–	55 (34)	50	RFP	D	30° OBLIQUE, FORCE LIMITED AND PRELOADED

*RUN 2016 UTILIZED 4.4 kN (1000 lb) LOAD-LIMITING WEBBING. ALL OTHER LOAD-LIMITING RUNS UTILIZED 6.7 kN (1500 lb) WEBBING.

Table 4.2-2

TASK 4 DATA STORED AT EDGEWOOD, MARYLAND

TAPE NO. 2338P4

INPUT PARAMETERS		OUTPUT DATA	
FILE NO.	FILE.ELEMENT	FILE NO.	FILE.
1	BKFILE2.R2010B	2	U82010B.
1	BKFILE2.R2016B	3	U82016B.
1	BKFILE2.R2017B	4	U82017B.
1	BKFILE2.R2018B	5	U82018B.
1	BKFILE2.R2019B	6	U82019B.
1	BKFILE2.R2027C	7	U82027C.
1	BKFILE2.R2031B	8	U82031B.
1	BKFILE2.R2032D	9	U82032D.
1	BKFILE2.R2028A	10	U82028A.
1	BKFILE2.R2029A	11	U82029A.
1	BKFILE2.R2116A	12	U82116A.
1	BKFILE2.R2118B	13	U82118B.
1	BKFILE2.R2119B	14	U82119B.
1	BKFILE2.R2201A	15	U82201A.
1	BKFILE2.R2202A	16	U82202A.
1	BKFILE2.R2208A	17	U82208A.
1	BKFILE2.R2209A	18	U82209A.
1	BKFILE2.R14DEG	19	U814DEG.
1	BKFILE2.R30DEG	20	U830DEG.

4.3 Lateral Impact Test

A secondary objective of this development program was to compare results obtained from lateral impact tests with and without pre-inflated energy absorbing modules. These modules were supplied by the CTM and consisted of a 'head bag' and a 'torso bag' mode from a rubberized material and designed to be attached to the right front passenger window and door panel. Configuration photos can be found in Appendix A, Run Number 2205 and 2206.

These tests were conducted with a 50th percentile ATD positioned as the right front passenger on the involved side of 90 degree, 33 Km/hr (20 MPH) sled tests. The first test, Run 2205, was conducted with the head bag at 'shape' pressure (approximately 2.5 cm (1 inch) water) and the torso bag at approximately 10 psi pressure. For the second test, Run 2206, pressure was increased to 5 psi in the head bag and 12 psi in the torso bag. Run 2207 was a 90 degree lateral sled test without the energy absorbing modules attached. Table number 4.3-1 presents the comparative results of these tests.

Table 4.3-1

LATERAL IMPACT COMPARISONS

Test No.	2205	2206	2207
Sled Velocity Km/h (MPH)	32.3 (20.2)	32.6 (20.4)	33.1 (20.7)
Head R. (G_R)	51	48	36*
HIC	207	215	171
Chest R. (G_R)	33	32	47
Pelvis R. (G_R)	26	37	32
Head Bag Pressure Initial/ Peak (PSI)	(1"H_2O)/(5.5)	(5.0)/(9.0)	N/A
Torso Bag Pressure Initial/ Peak (PSI)	(10.0)/(15.0)	(12.0)/(16.0)	N/A

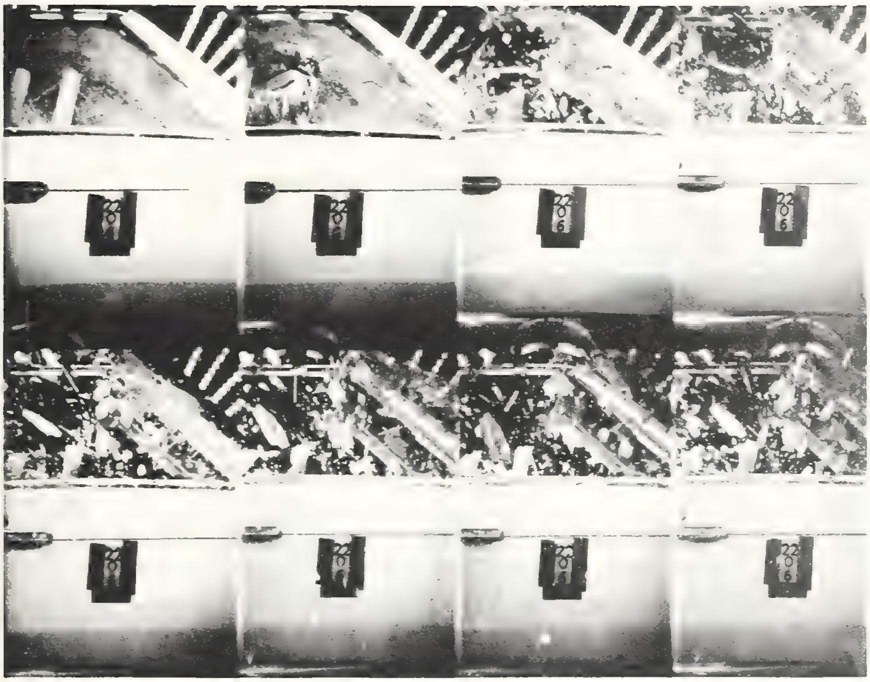
*Test conducted with broken right front window.

During Tests Nos. 2205 and 2206 the primary head resultant component was G_Y. During Test No. 2207 the primary component was G_Z. This was caused by the fact that, during Test No. 2206 the window shattered (Figure 4.3-1) and therefore there was no window in place during Test No. 2207.

The air cushions performed as expected. These devices filled the space between the ATD and the door, window, and header area and provided a controlled ridedown for the occupant in Test Nos. 2205 and 2206. In Test No. 2207 there was approximately four inches between the ATD and the door at the start of the test. This dimension allowed a relative velocity between the occupant and the door at the time of contact and is reflected in the higher chest acceleration.

Two lateral sled tests were conducted with a 50th percentile ATD as the belted occupant on the uninvolved side of a simulated 90 degree, 34 Km/h (21 MPH) crash. The objective of these tests was to compare the results obtained from a non-preloaded passive torso belt system and a statically pre-loaded torso belt system. Table No. 4.3-2 presents the comparative results of these tests.

The ATD in Test No. 2208 slipped laterally out of the shoulder strap and was restrained solely in the abdominal area by the belt. The static pre-loading used in Test No. 2209 was effective in restraining the ATD in an upright position. Primary belt loading, 10.4 kN (2350 lbs) was applied to the hip of the ATD. This loading mechanism would be preferable to the abdominal loading observed in Test No. 2208.



RUN 2206

Figure 4.3-1 SEQUENCE CAMERA PHOTOGRAPH OF TEST NO. 2206

Table 4.3-2

LATERAL BELTED TESTS

Test No.	2208	2209
Preload kN (lbs.)	None	1.3 (300) Static
Webbing	Nylon	Nylon
Sled Velocity Km/h (MPH)	33.9 (21.2)	33.4 (20.9)
Head R. (G_R)	64	33
HIC	592	162
Chest R. (G_R)	19	20
Pelvis R. (G_R)	20	19
Upper Torso Belt kN (lbs.)	5.4 (1210)	7.1 (1600)
Lower Torso Belt kN (lbs.)	3.6 (820)	10.4 (2350)

5.0 DISCUSSION OF RESULTS

Presented in this section are selected results (for ease of comparison) along with a narrative description of the experimental development and evaluation phase of this work.

5.1 Use Indication

One of the objectives of the development of this belt restraint system was that it provides for an indication of usage. The interpretation of use indication is that the restraint system must graphically indicate that, not only was the belt in use at the time of the crash but, more importantly, whether the belt system has been subjected to loads that require its replacement if the vehicle is repairable. While it is unlikely that it would currently be cost beneficial to repair a small car that had undergone a collision at velocity changes in excess of 48 Km/h (30 MPH), use indication would be advantageous to the accident investigation and occupant protection evaluation disciplines.

As stated earlier, and with both of these reasons for use indication having been taken into account, the Takata-Kojyo webbing was selected as the most likely system component to provide both use indication and consistently reliable force limiting in a near production restraint system (Reference 4 and 7). The high level use indication capability of this material is displayed in the differences in appearance of the webbing that are apparent between the pre-test and post-test photographs of Figures 5.1-1 and 5.1-2, respectively. Once the normally monochromatic (in this reported work the webbing was black, however the manufacturing process would allow the use of colored fibers) webbing (Figure 5.1-1) is stressed beyond its design load, white fibers appear (Figure 5.1-2). This phenomenon was apparent after loading on all of the levels of force limiting webbing used in this program (2.2, 4.4 and 6.7 kN (500, 1000 and 1500 lbs)).

Figure 5.1-1 TAKATA-KOJYO WEBBING PRIOR TO LOADING

Figure 5.1-2 TAKATA-KOJYO WEBBING AFTER 6.7 kN (1500 lbs) LOADING

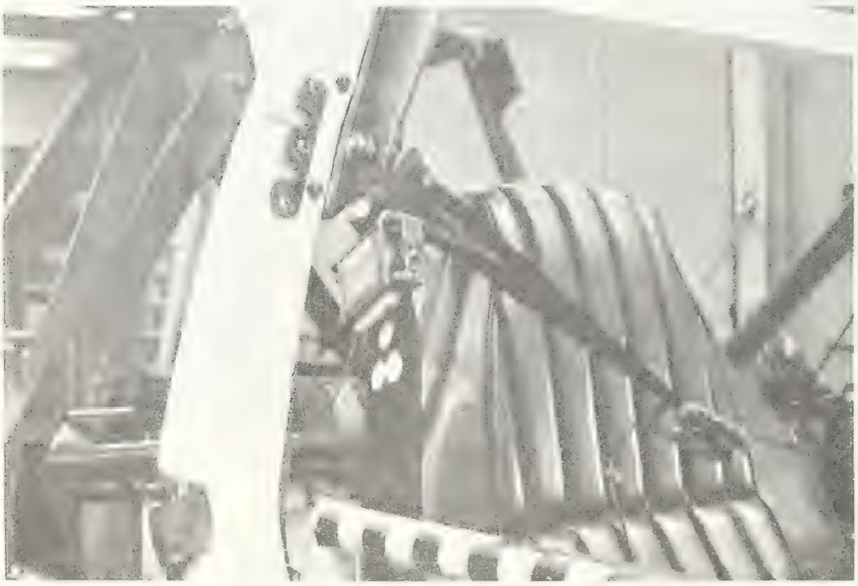
The AB-Stil web shredding D-ring used in Tests No. 2024 and 2025 with polyester and nylon webbing, respectively, functions well as a use indicator due to the web shredding effect (Figure 5.1-3). Unfortunately (as will be discussed in Section 5.2, Force Limiting) there was no strong indicator that a force limiting capability was present.

5.2 Force Limiting

Table 5.2-1 presents the sled test data for comparison of the results obtained from a 50th percentile ATD right front passenger at 54 Km/h (34 MPH) velocity change. This table displays data from the baseline system (Test No. 2011), the 4.4 kN (1000 lbs.) force limited, preloaded system (Test No. 2016), the 6.7 kN (1500 lbs.) force limited, preloaded system (Test No. 2017) and two web shredding, non-preloaded tests using polyester and nylon webbing (Test Nos. 2024 and 2025). The parameters held constant in these tests were: the ATD, the seat position and the sled velocity change. The energy managing knee bar (No. 1) was different (stiffer) for Test No. 2011 than for the four other tests (kneebar no. 3). This notwithstanding, it is seen that, with regard to upper torso belt load, the force limited (6.7 kN (1500 lb.)) preloaded system is superior to the others overall. At first glance it might appear anamolous that the upper torso belt load on Test No. 2016 wherein 4.4 kN (1000 lbs.) force limiting webbing was used is higher than that of Test No. 2017 wherein 6.7 kN (1500 lbs.) webbing was used. This difference is explained when one considers that the 4.4 kN (1000 lbs.) webbing is a 20% stretch material while the 6.7 kN (1500 lbs.) webbing is a 40% stretch material. During Test No. 2016, once the 20% stretch capability was used the material reverted to its basic nylon characteristics and the loads increased.

Head excursions in the X-direction were not significantly different in any of these tests. There was no head contact with the vehicle interior components during impact.

a. TEST NO. 2024 – POLYESTER WEBBING



b. TEST NO. 2025 – NYLON WEBBING

Figure 5.1-3 AB STIL WEB SHREDDING D-RING

Table 5.2-1

SLED TEST DATA
FORCE LIMITING COMPARISONS
50TH PERCENTILE ATD RIGHT FRONT PASSENGER

TEST NO.	2011	2016	2017	2024	2025
FORCE LIMITING kN (lbs)	NONE	4.44 (1000)	6.67 (1500)	AB STIL	AB STIL
PRELOADER	NONE	REPA	REPA	NONE	NONE
WEBBING	NYLON	TAKATA-KOJYO	TAKATA-KOJYO	POLYESTER	NYLON
SLED VELOCITY Km/h (mph)	53.8 (33.6)	53.9 33.7)	53.9 (33.7)	53.9 (33.7)	54.1 (33.8)
HEAD R. (G_R)	60	40	44	66	46
HIC	555	240	230	589	390
CHEST R. (G_R)	42	36	36	50	35
LEFT FEMUR kN (lbs)	7.42 (1625)	6.89 (1550)	7.11 (1600)	6.33 (1425)	6.44 (1450)
RIGHT FEMUR kN (lbs)	7.57 (1700)	7.33 (1650)	7.11 (1600)	7.11 (1600)	7.22 (1625)
UPPER TORSO BELT kN (lbs)	9.35 (2100)	7.78 (1750)	5.78 (1300)	11.56 (2600)	8.89 (2000)
LOWER TORSO BELT kN (lbs)	6.77 (1500)	4.00 (900)	5.11 (1150)	9.56 (2150)	8.22 (1850)
HEAD EXCURSION -X cm (ins)	6.62 (24.5)	64.0 (25.2)	62.5 (24.6)	60.7 (23.9)	62.5 (24.6)

FMVSS 208 PEC values were well within the desired 75% level on all tests. However, when comparing the upper torso belt loads to head excursion four things are apparent. (1) there is little difference between the baseline system and the web shredding system with nylon webbing, (2) the web shredding system using polyester webbing is the minimum performer of all systems, (3) the 4.4 kN (1000 lbs.) preloaded webbing is probably too low of a level to attain protection at speeds in excess of 54 Km/h (34 MPH) and (4) the 6.7 kN (1500 lbs.) preloaded webbing is the maximum performer of the set. Based upon these observations (as stated in Section 5.1) the AB Stil web shredding device was not tested further.

Having determined that the most promising force limiting system for small cars was comprised of the 6.7 kN (1500 lbs.) Takata-Kojyo webbing, preloading and the design no. 3 energy managing knee bar it was required that both velocity changes as well as ATD size differences be investigated. Since it had been decided that the 50th percentile ATD right front passenger would be the primary surrogate, comparative tests were made with velocity change being the only variable. Table 5.2-2 presents the results of data obtained from three sled tests at 54 Km/h (34 MPH), 64 Km/h (40 MPH) and 72 Km/h (45 MPH).

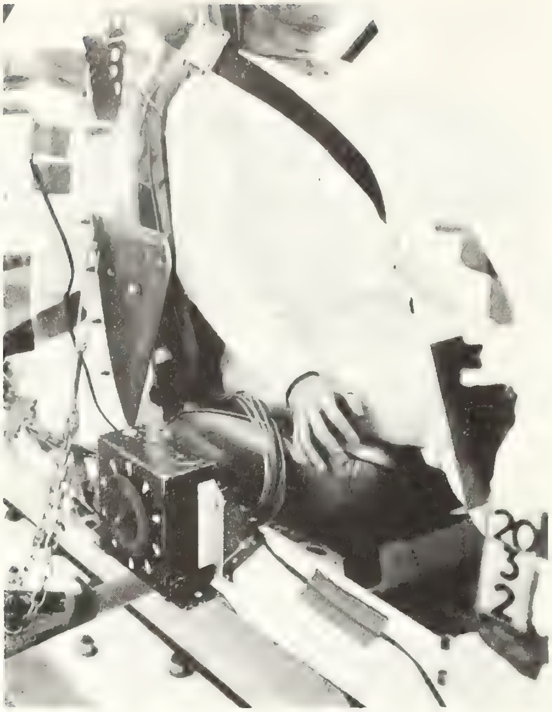
All FMVSS 208 PEC were met in these tests but the goal of 75% on HIC and chest resultant were exceeded at a velocity change of 72 Km/h (45 MPH) (Test No. 2031). The belt load target of 6.7 kN (1500 lbs.) was not exceeded and no head contact with vehicle interior parts were noted upon impact.

In an effort to determine if the performance could be improved at 72 Km/h (45 MPH) if the preloading were static (and constant) as opposed to dynamic (and transient) a sled test was conducted (Test No. 2032) with a static preload of 1.3 kN (300 lbs.) on the belt as recorded by the upper torso belt Lebow belt load transducer. The static preloading was accomplished by means of tightening the belt with a turnbuckle (Figure 5.2-4) that had one of its ends attached to the sled carriage structure. The turnbuckle was tightened until the output of the belt transducer recorded 1.8 kN (400 lbs.). Due to ATD flesh compliance and automotive seat compliance the force level in the belt

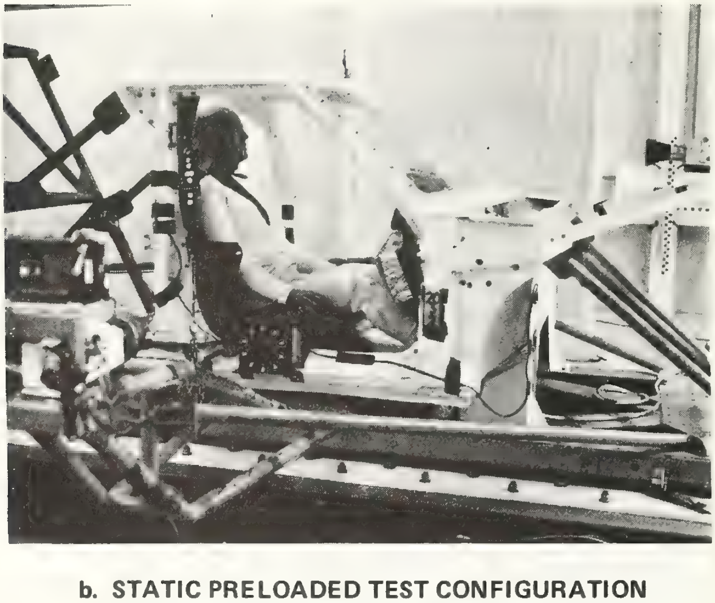
Table 5.2-2

SLED TEST DATA
VELOCITY CHANGE COMPARISONS
50TH PERCENTILE ATD RIGHT FRONT PASSENGER
PRELOADED, FORCE LIMITED BELT SYSTEM

TEST NO.	2017	2027	2031
FORCE LIMITING kN (lbs)	6.67 (1500)	6.67 (1500)	6.67 (1500)
PRELOADER	REPA	REPA	REPA
WEBBING	←	TAKATA-KOJYO	→
SLED VELOCITY Km/h (mph)	53.9 (33.7)	63.2 (39.5)	71.4 (44.6)
HEAD R. (G_R)	44	49	85
HIC	230	436	890
CHEST R. (G_R)	36	33	47
LEFT FEMUR kN (lbs)	7.11 (1600)	7.00 (1575)	6.67 (1500)
RIGHT FEMUR kN (lbs)	7.11 (1600)	7.20 (1620)	7.67 (1725)
UPPER TORSO BELT kN (lbs)	5.78 (1300)	6.67 (1500)	6.00 (1500)
LOWER TORSO BELT kN (lbs)	5.11 (1150)	5.33 (1200)	5.11 (1150)
HEAD EXCURSION -X cm (ins)	62.5 (24.6)	67.8 (26.7)	77.5 (30.5)



a. STATIC PRELOADING MECHANISM



b. STATIC PRELOADED TEST CONFIGURATION

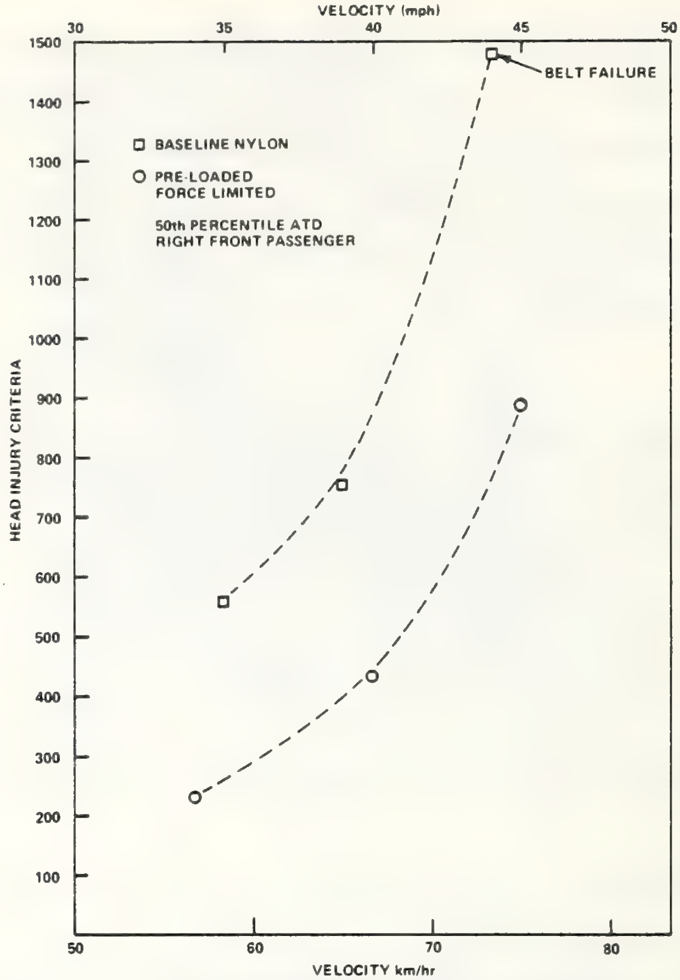
Figure 5.2-4 STATIC PRELOADING

at the time of the sled test was 1.3 kN (300 lbs.). The results of this test are presented in Table No. 5.2-3 along with the results of Test No. 2031, the comparable dynamic preloaded test. It is seen from Table No. 5.2-3 that the results, with regard to HIC and head excursion in the X-direction, were improved by the static preloading but the chest resultant acceleration and upper torso belt loads were denegrated.

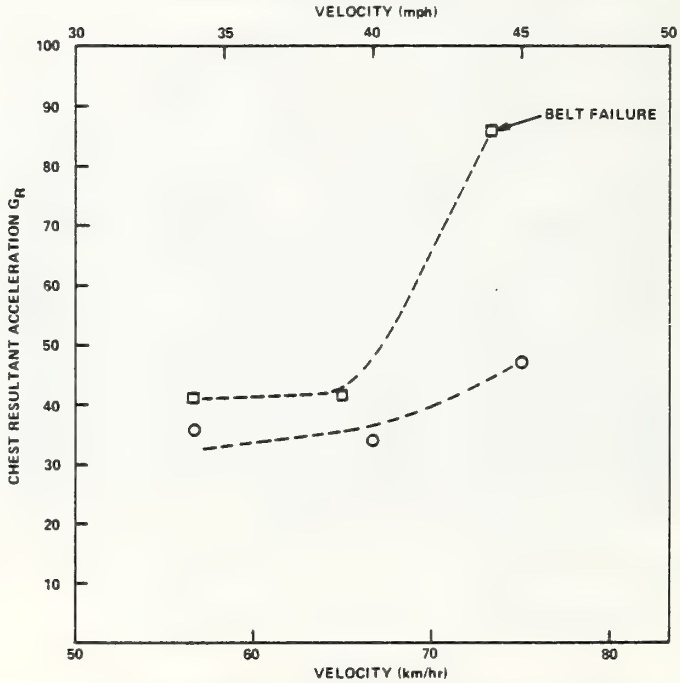
The baseline belt system (no preloading, no force limiting and nylon webbing) was tested at velocity changes of 54 Km/h (34 MPH), 64 Km/h (40 MPH) and 72 Km/h (45 MPH) to compare with the results of the preloaded force limited system. Table No. 5.2-4 presents the summary data from these tests. Comparisons of these data with the data presented in Table No. 5.2-2 is presented in Figure 5.2-5. It is apparent from this figure that the preloaded force limited belt restraint system is superior in performance to the baseline system both with regard to HIC and chest resultant acceleration as a function of velocity.

Comparative data for the 5th percentile female, 50th percentile male and 95th percentile male sized ATDs exposed to sled tests at 54 Km/h (34 MPH) while restrained with the preloaded, force limited belt system are presented in Table 5.2-5. All of these subjects riding as the right front passenger produced FMVSS 208 PEC well below the 75% limit. While electrical noise overriding the 5th percentile female head acceleration data precluded the meaningful calculation of a HIC value, it is estimated that the magnitude of the HIC would have been less than 750 (see data traces for Test No. 2021 in Appendix A).

Table 5.2-6 shows that under the same test conditions but with a belt system that is non-preloaded and non-force limited the results obtained from the different sized ATDs are of a much higher level. During Test No. 2020 as was the situation in Test No. 2021 there was electrical noise overriding the head acceleration data that precluded the obtaining of a HIC number. In this case however it is doubtful that the HIC value would have fallen below the FMVSS 208 PEC limit of 1000 (see Appendix A, Test No. 2020).



a. HEAD INJURY CRITERIA AS A FUNCTION OF VELOCITY



b. CHEST RESULTANT ACCELERATION AS A FUNCTION OF VELOCITY

Figure 5.2-5 COMPARISON OF BASELINE SYSTEM AND FORCE – LIMITED, PRELOADED SYSTEM AT DIFFERENT VELOCITIES FOR 50th PERCENTILE RIGHT FRONT PASSENGER ATDs

Table 5.2-3

SLED TEST DATA
DYNAMIC VERSUS STATIC
PRELOADING COMPARISONS
50TH PERCENTILE ATD
RIGHT FRONT PASSENGER

TEST NO.	2031	2032
FORCE LIMITING kN (lbs)	6.67 (1500)	6.67 (1500)
PRELOADER kN (lbs)	REPA	1.33 (300) STATIC
WEBBING	TAKATA-KOJYO	TAKATA-KOJYO
SLED VELOCITY Km/h (mph)	71.4 (44.6)	71.7 (44.8)
HEAD R. (G_R)	85	65
HIÇ	890	491
CHEST R. (G_R)	47	54
LEFT FEMUR kN (lbs)	6.67 (1500)	7.11 (1600)
RIGHT FEMUR kN (lbs)	7.67 (1725)	7.33 (1650)
UPPER TORSO BELT kN (lbs)	6.00 (1350)	7.33 (1650)
LOWER TORSO BELT kN (lbs)	5.11 (1150)	5.11 (1150)
HEAD EXCURSION -X cm (ins)	77.5 (30.5)	74.9 (29.5)

Table 5.2-4

SLED TEST DATA
VELOCITY CHANGE COMPARISONS
50TH PERCENTILE ATD RIGHT FRONT PASSENGER
BASELINE BELT SYSTEM

TEST NO.	2011	2201	2202
FORCE LIMITING kN (lbs)	NONE	NONE	NONE
PRELOADER	NONE	NONE	NONE
WEBBING	NYLON	NYLON	NYLON
SLED VELOCITY Km/h (mph)	53.8 (33.6)	62.6 (39.1)	71.0 (44.4)
HEAD R. (G_R)	60	60	152
HIC	555	752	1475
CHEST R. (G_R)	42	42	86
LEFT FEMUR kN (lbs)	7.42 (1625)	6.7 (1500)	6.7 (1500)
RIGHT FEMUR kN (lbs)	7.57 (1700)	6.8 (1530)	6.7 (1500)
UPPER TORSO BELT kN (lbs)	9.35 (2100)	10.5 (2350)	10.0 (2250)*
LOWER TORSO BELT kN (lbs)	6.68 (1500)	9.0 (2020)	10.9 (2440)

*BELT BROKE AT 72 ms

Table 5.2-5

SLED TEST DATA
PRELOADED, FORCE LIMITED COMPARISONS
5TH, 50TH AND 95TH PERCENTILE ATDs
RIGHT FRONT PASSENGER

TEST NO.	2021	2017	2029
ATD	5th	50th	95th
FORCE LIMITING kN (lbs)	6.67 (1500)	6.67 (1500)	6.67 (1500)
PRELOADER	REPA	REPA	REPA
WEBBING	←	TAKATA-KOJYO	→
SLED VELOCITY Km/h (mph)	54.1 (33.8)	53.9 (33.7)	54,6 (34,1)
HEAD R. (G_R)	54	44	42
HIC	-	230	292
CHEST R. (G_R)	40	36	34
LEFT FEMUR kN (lbs)	2.89 (650)	7.11 (1600)	6,18 (1390)
RIGHT FEMUR kN (lbs)	2.89 (650)	7.11 (1600)	6.84 (1540)
UPPER TORSO BELT kN (lbs)	5.56 (1250)	5.78 (1300)	7.78 (1750)
LOWER TORSO BELT kN (lbs)	4.44 (1000)	5.11 (1150)	5.56 (1250)
K.B. PENETRATION LT. cm (ins)	8,6 (3.38)	12.0 (4.72)	15.8 (6.23)
K.B. PENETRATION RT. cm (ins)	7.3 (2,88)	12,5 (4.91)	18.9 (7.43)
HEAD EXCURSION -X cm (ins)	48.9 (19.2)	62.5 (24.6)	68.1 (26.8)

Table 5.2-6

SLED TEST DATA
BASELINE COMPARISONS
5TH, 50TH AND 95TH PERCENTILE ATDs
RIGHT FRONT PASSENGER

TEST NO.	2020	2011	2028
ATD	5th	50th	95th
FORCE LIMITING kN (lbs)	NONE	NONE	NONE
PRELOADER	NONE	NONE	NONE
WEBBING	POLYESTER	NYLON	NYLON
SLED VELOCITY Km/h (mph)	53.9 (33.7)	53.8 (33.6)	54.5 (34.0)
HEAD R. (G_R)	140	60	>200
HIC	-	555	1080
CHEST R. (G_R)	60	42	48
LEFT FEMUR kN (lbs)	2.67 (600)	7.24 (1625)	6.22 (1400)
RIGHT FEMUR kN (lbs)	3.11 (700)	7.57 (1700)	7.67 (1725)
UPPER TORSO BELT kN (lbs)	9.11 (2050)	9.35 (2100)	9.33 (2100)
LOWER TORSO BELT kN (lbs)	8.22 (1850)	6.68 (1500)	8.00 (1800)
HEAD EXCURSION -X cm (ins)	42.9 (16.9)	62.2 (24.5)	73.7 (29.0)

Figure 5.2-6 presents the chest resultant acceleration and the head resultant acceleration as a function of ATD size for both the baseline and the preloaded force limited belt systems obtained in 54 Km/h (34 MPH) sled tests.

Comparisons of these results serve to demonstrate that for all three sizes of ATDs in the right front passenger position the pre-loaded force limited torso belt system with an energy managing knee bar is superior in performance at 54 Km/h (34 MPH) sled velocity to that of a non-preloaded, non-force limited belt system with an energy managing knee bar at the same velocity changes.

It was recognized at the outset of the program that the control of the occupant kinematics would contribute significantly to the success of the restraint system for use in small cars. In an effort to determine whether the control attained by the energy managing knee bar design would be denegrated by the use of an active lap belt, Test No. 2018 was conducted. The force limiting level chosen for the lap belt was 2.2 kN (500 lbs.). This force limiting level, it was believed, would be sufficient to restrain occupants in roll over and lateral crash situations while allowing for reasonable knee stroking action in frontal collisions.

Table No. 5.2-7 presents the summary data obtained during this test along with the data obtained from a test wherein the lap belt was not used. It can be seen that while the HIC value increased the chest resultant acceleration maximum decreased. The femur loads and knee bar penetrations were decreased as would be expected with the use of a lap belt. Head excursion was increased because of the slight jackknifing of the ATD caused by the lap belt. There was no head contact during this test but the 66 cm (26 in.) measured excursion brought the ATDs head within approximately 1.25 cm (0.5 in.) from the windshield.

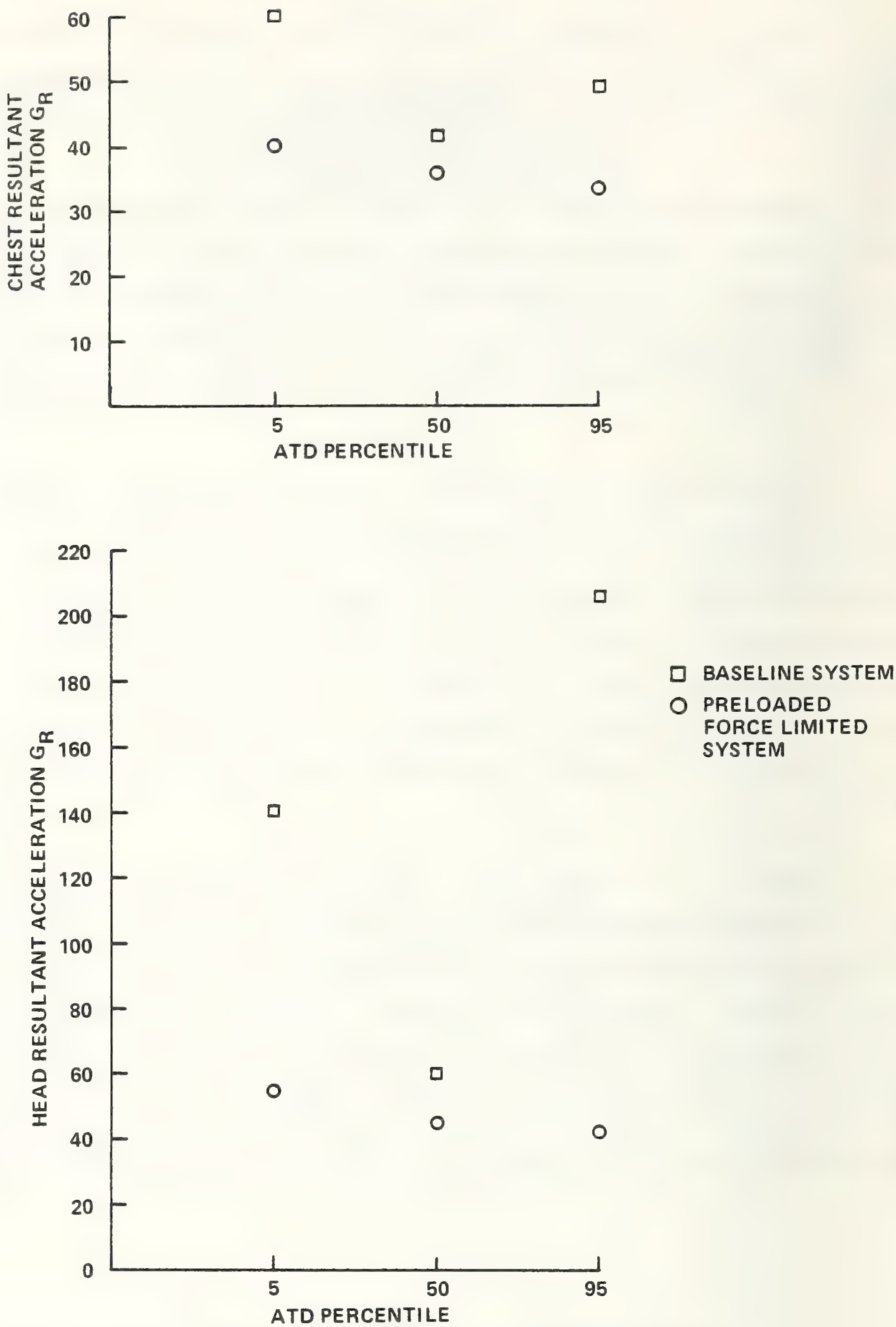


Figure 5.2-6 CHEST AND HEAD RESULTANT ACCELERATIONS AS A FUNCTION OF ATD SIZE AT 54 KM/H (34 MPH)

Table 5.2-7

SLED TEST DATA
FORCE LIMITING COMPARISONS
PRELOADING AND
PRELOADING WITH LAPBELT
50th PERCENTILE ATD RIGHT FRONT PASSENGER

TEST NO.	2017	2018
FORCE LIMITING kN (lbs)	6.67 (1500)	6.67 (1500)/ 2.22 (500)
PRELOADER	REPA	REPA
WEBBING	← TAKATA-KOJYO →	
SLED VELOCITY Km/h (mph)	53.9 (33.7)	53.8 (33.6)
HEAD R. (G_R)	44	>100
HIC	230	478
CHEST R. (G_R)	36	32
LEFT FEMUR kN (lbs)	7.11 (1600)	5.78 (1300)
RIGHT FEMUR kN (lbs)	7.11 (1600)	5.33 (1200)
UPPER TORSO BELT kN (lbs)	5.78 (1300)	6.00 (1350)
LOWER TORSO BELT kN (lbs)	5.11 (1150)	4.89 (1100)
LAP BELT kN (lbs)	NONE	2.22 (500)
K.B. PENETRATION LT. cm (ins)	12.0 (4.72)	8.2 (3.23)
K.B. PENETRATION RT. cm (ins)	12.5 (4.91)	9.6 (3.79)
HEAD EXCURSION - X cm (ins)	62.5 (24.6)	66.0 (26.0)

It is apparent, even though the FMVSS 208 PEC are near the 50% level when one considers the ATD kinematics and the proximity to vehicle internal surfaces during the test, that the system is denegrated by the use of the force limited active lap belt. It is believed that the situation would worsen with the use of a standard nylon or polyester lap belt.

The preloaded force limited belt system did not perform as well for the driver as it did for the right front passenger. Table 5.2-8 presents baseline system and force limited system data for comparison. During all three tests there was head and chest contact with the steering wheel rim and chest contact with the steering wheel hub was experienced during Test No. 2120. The results of Test No. 2118 indicate lower HIC and chest resultant values than those obtained from the baseline test (Test No. 2119). The torso belt loads are considerably less. The chest resultant acceleration obtained on the driver ATD during Test No. 2120 (a slightly higher velocity change than Test No. 2118) exceeded the FMVSS 208 PEC by 5 G_R and this value was 60% larger than the values recorded during Test No. 2118. It is believed that this phenomenon indicates that for a driver system the 40% stretch webbing allows too much stroking distance even when preloaded. A lower percentage stretch webbing and/or a higher level of force limiting may be required in order for a similar level of performance to that obtained with the right front passenger system to be realized.

Table 5.2-8

SLED TEST DATA
BASELINE VS. FORCE LIMITED SYSTEMS
50TH PERCENTILE ATD DRIVER

TEST NO.	2119 DR	2118 DR	2120 DR
FORCE LIMITING kN (lbs)	NONE	6.7 (1500)	6.7 (1500)
PRELOADER	NONE	REPA	REPA
WEBBING	NYLON	← TAKATA-KOJYO	→
SLED VELOCITY Km/h (mph)	54.1 (33.8)	54.2 (33.9)	57.4 (35.9)
HEAD R. (G_R)	150	200	>200
HIC	830	774	811
CHEST R. (G_R)	46	39	65
LEFT FEMUR kN (lbs)	6.9 (1560)	7.1 (1600)	6.9 (1550)
RIGHT FEMUR kN (lbs)	6.6 (1480)	6.7 (1500)	6.5 (1450)
UPPER TORSO kN (lbs)	9.2 (2075)	6.3 (1425)	6.2 (1400)
LOWER TORSO kN (lbs)	7.5 (1675)	6.2 (1400)	6.5 (1450)

5.3 Preloading

Inherent in any belt restraint system is the requirement that a certain length of webbing be stored on the spool of the ELR after belt deployment. The length of stored webbing is increased in a passive belt system. The webbing is loosely wound up on the spool after a normal belt deployment and during a crash, once the ELR has locked and the occupant starts to load the belts, the webbing tightens on the spool. Depending upon the length of stored webbing (the number of wraps about the spool) a certain length will 'spool-off' at a relatively low force level. This 'spool-off' essentially lengthens the belt while absorbing very little of the crash energy. The problems associated with 'spool-off' in occupant protection systems have been recognized for many years (References 8, 9, 10) and various solutions to them have been attempted.

The philosophy utilized in the development of this reported restraint system was to use near production components. With regard to the 'spool-off' problem, two belt pretensioners were available with a near production capability. Both of these pretensioners had been designed and tested for use with an active lap and shoulder strap (continuous loop) belt system. One, manufactured by Repa Feinstanzwerk GMBH, is a pelton turbine wheel driven by liquid which is propelled towards the wheel by a gas generator. The wheel, attached to the spool, turns counter to the spool-off direction and tightens the loosely wound webbing. The second belt pretensioner, manufactured by FFV Sweden, is a linear device that, by means of a D-ring through which the belt passes, can pull the belt very rapidly to tighten the webbing on the spool, thereby eliminating the 'spool off' affect.

In an actual car both of these pretensioners would require the use of a crash sensor for actuation of the pyrotechnic gas generator. In these reported tests the firing time of the gas generators was set at 8 ms after time zero (time zero on the Calspan HYGE sled is defined as that time when the sled experiences an acceleration of 0.25 G_X). This is approximately the same actuation time that is used during tests of air cushion restraint systems.

Reidelbach has reported (Reference 8) that when comparing preloaded and non-preloaded belt systems the accelerations on the head are reduced by 57% and accelerations on the chest are reduced by 15.7%. In the work reported herein the observed percentages were 23% and 5%, respectively, for both nylon webbing and the 6.7 kN (1500 lbs.) Takata-Kojyo webbing. It must be understood, however, that these data have not been obtained from identical restraint systems and therefore a descrepancy in results may not exist.

Figure 5.3-1 presents data relevant to the spool off problem. Displayed in this figure are chest resultant acceleration as a function of spool off length, upper torso belt loads as a function of spool off length and upper torso belt loads as a function of chest resultant acceleration. It is seen that for a nylon belt system both chest accelerations and belt loads increase with increasing spool off length but these parameters remain relatively constant for the force limited belt system. Included in these graphs are the results from one test with the AB Stil web shredding D-ring used with nylon webbing and one used with polyester webbing. Unfortunately there is only one data point for each of these webbing materials. The nylon webbing, when shredded, provides lower chest accelerations and belt loads for the same amount of spool off than does the non-shredded webbing. The polyester webbing on the other hand provides significantly higher accelerations and loads. The dynamic loading results of nylon and polyester webbing deserve further investigation.

With regard to the occupants chest resultant acceleration it is noted that there is little effect from preloading in this force limiting restraint system. For standard nylon belt systems this is not the case as both belt loads and chest accelerations increase as a function of the effectiveness of preloading on eliminating spool-off.

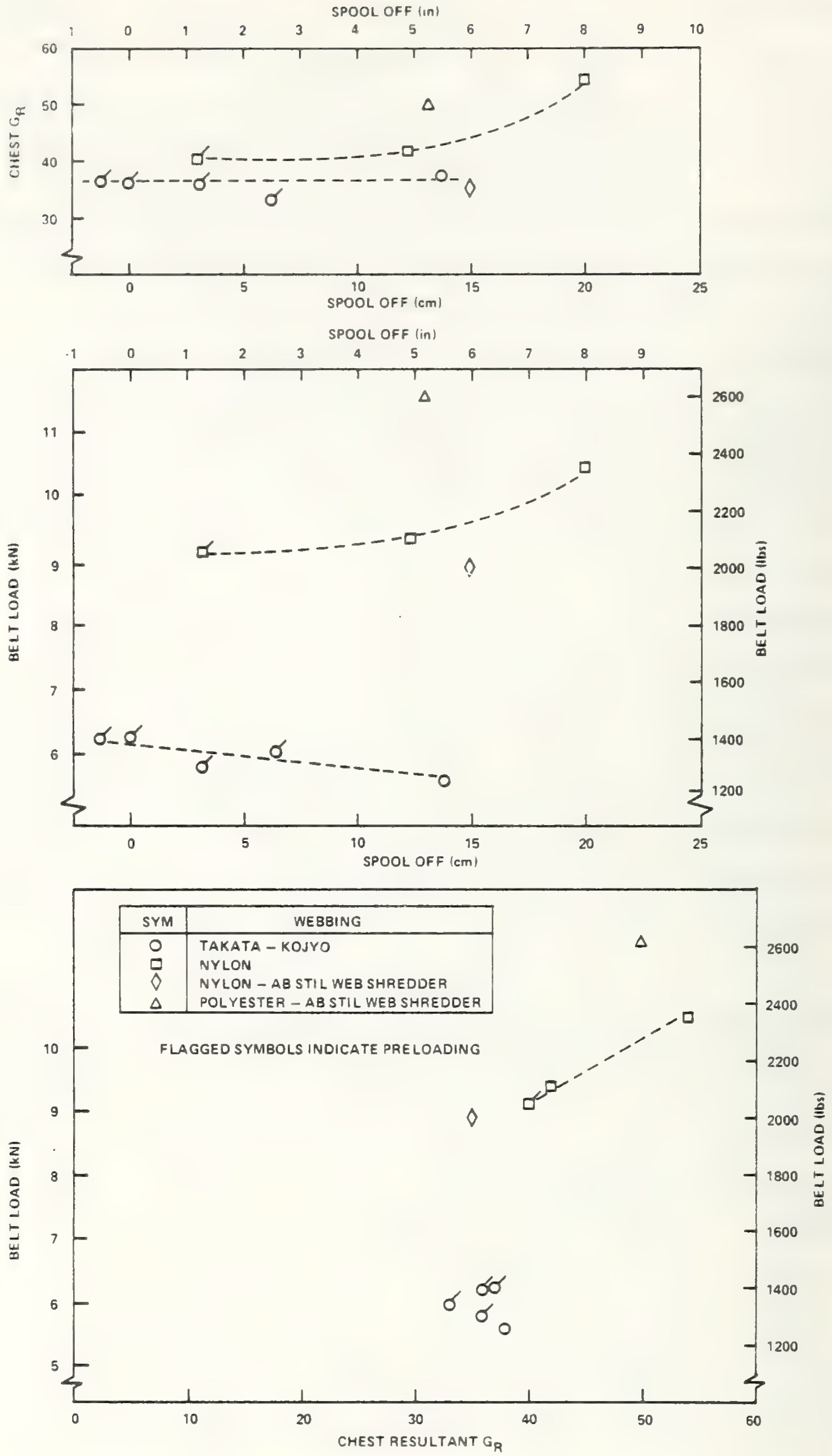


Figure 5.3-1 CHEST RESULTANT, BELT LOAD AND SPOOL OFF EFFECT COMPARISONS FOR BASELINE, BASELINE WITH WEB SHREDDER AND FORCE LIMITED, PRE-LOADED BELTS

Table 5.3-1

SLED TEST DATA
PRELOADING COMPARISONS
50TH PERCENTILE ATD
RIGHT FRONT PASSENGER

TEST NO.	2016	2026
FORCE LIMITING kN (lbs)	4.44 (1000)	4.44 (1000)
PRELOADER	REPA	FFV
WEBBING	TAKATA-KOJYO	TAKATA-KOJYO
SLED VELOCITY Km/h (mph)	53.9 (33.7)	53.9 (33.7)
HEAD R. (G_R)	40	54
HIC	240	390
CHEST R. (G_R)	36	34
LEFT FEMUR kN (lbs)	6.89 (1550)	6.22 (1400)
RIGHT FEMUR kN (lbs)	7.33 (1650)	6.67 (1500)
UPPER TORSO BELT kN (lbs)	7.78 (1750)	5.78 (1300)
LOWER TORSO BELT kN (lbs)	4.00 (900)	4.67 (1050)
HEAD EXCURSION - X cm (ins)	64.0 (25.2)	73.9 (29.1)

Table No. 5.3-1 presents the data obtained from sled tests conducted at 54 Km/h (34 MPH) of the two types of pretensioners. 4.4 kN (1000 lbs.) force limiting webbing was used in the system for these tests. As stated earlier the upper torso belt loads are above 4.4 kN (1000 lbs.) because the force limiting webbing reverts to nylon characteristics once the 20% stretch at 4.4 kN (1000 lbs.) is fully utilized. These tests indicated that both pretensioners functioned as designed and since the Repa system was more readily available in quantity and integral with an ELR it was chosen as the primary belt pretensioner for this program.

In an effort to determine the effectiveness of the belt pretensioner (pre-loader) post-test measurements of the amount of spool off from sled tests were averaged. Only the data generated by 50th percentile ATDs at a sled velocity change of 54 Km/h (34 MPH) were used to determine the numbers presented in Table 5.3-2.

Table 5.3-2

AVERAGE SPOOL OFF

Preloaded*	Non-Preloaded**
2.62 cm (1.03 in.)	14.12 cm (5.56 in)

*Average of 8 tests.

**Average of 7 tests.

5.4 The Six Year Old-Sized ATD Problem

Early in the course of the contract sled testing, a serious problem with regard to protection of the 6 year old sized ATD in a passive torso belt system was discovered. While attempting to obtain results for the baseline restraint system (Test No. 2022), a nylon torso belt only, the ATD restraint was observed to be by the mechanism of the belt loading the neck and left axilla only. Run No. 2030 was conducted with the upper anchor point location lowered in the vehicle by 25 cm (10 in.) in an effort to attain a more optimum belt deployment over the right shoulder and thereby eliminate the neck loading. The results of this test were essentially the same as they had been for the previous 6 year old ATD test.

During Run 2198, the six year old Sierra ATD was restrained by baseline nylon webbing in the two-point passive configuration plus a 2.2 kN (500 lb.) force limiting lap belt. The lap belt reached maximum elongation and a head severity index (HSI) of 3750 was generated. Run 2199 was configured in the same manner using nylon lap belt webbing and this run also generated an excessive HSI (5000) and a chest resultant of 60 G_R. It was decided, in consultation with the CTM, to place the ATD on a bolster. A 10 cm (4 in.) bolster was placed under the ATD but the torso belt deployment appeared too close to the neck. Consequently, a 20 cm (8 in.) bolster was used under the ATD and the belt geometry looked quite reasonable. This configuration was then sled tested (Run 2200) using nylon torso and lap belt webbing, but again an excessively high HSI (>5000) was calculated. An Alderson six year old-sized ATD was tested in this same configuration (i.e., 8 in. bolster) in sled Test 2204 and the electronic data produced an HSI of 700 and a chest resultant of 40 G_R.

Table No. 5.4-1 presents the comparative data obtained from the two manufacturer's ATDs exposed in replicate tests. In addition to the obvious differences in FMVSS 208 PEC, the kinematics of the surrogates differed greatly. It was observed from the high speed movies that the shoulder strap not only did not load the neck of the Alderson ATD but rather slipped off of the shoulder causing probable soft tissue loading in the abdominal area. Because of the differences observed in ATD responses, there was no attempt made to use the force limited belt system with them.

Table No. 5.4-1

SLED TEST DATA
6 YEAR OLD SIZE ATD COMPARISONS
8 INCH BOLSTER
NYLON TORSO AND LAP BELT

TEST NO.	2200	2204
ATD	SIERRA	ALDERSON
SLED VELOCITY Km/h (mph)	53.9 (33.7)	53.8 (33.6)
HEAD R. (G_R)	160	70
HIC	4657	532
CHEST R. (G_R)	55	40
UPPER TORSO BELT kN (lbs)	5.7 (1280)	3.3 (750)
LOWER TORSO BELT kN (lbs)	4.4 (1000)	2.3 (520)
LEFT LAP BELT kN (lbs)	2.7 (600)	3.2 (710)
RIGHT LAP BELT kN (lbs)	2.2 (500)	2.8 (620)

This problem of ATD variability is the subject of the investigation that has been contracted under the optional Task 7 provision of the original Statement of Work. It is currently planned that this investigation will be completed and reported by December 31, 1979.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based upon these limited numbers of tests it may be concluded that:

1. A torso belt restraint system with passive capability, force limited at 6.7 kN (1500 lbs.), is feasible for adult occupant protection at frontal crash speed above 48 Km/h (30 MPH) in a small car.

2. Preloading of the torso belt is not required in order to meet FMVSS 208 performance criteria for a 50th percentile ATD right front passenger at 48 Km/h (30 MPH).

3. With dynamic preloading, FMVSS 208 performance criteria can be met for a 50th percentile male size ATD right front passenger at sled velocities up to 72 Km/hr (45 MPH).

4. Protection at higher test velocities may be attained with higher level, longer duration preloading than is currently available.

5. 50th percentile drivers and 95th percentile right front passengers may also require a higher level of force limiting in order to meet FMVSS 208 performance criteria at speeds above 48 Km/hr (30 MPH) velocities.

6. 6 year old size ATDs may not be properly protected by an adult belt restraint system.

7. The CVS III program, when supplied with the proper input parameters, can be used to simulate a frontal sled test of a 50th percentile ATD.

6.2 Recommendations

1. Additional developmental testing should be conducted to define the optimum force limiting and preloading values as functions of occupant size, occupant position and crash velocity.

2. The system should be evaluated in full scale frontal barrier tests.

3. FMVSS 209 should be amended to allow the use of a torso belt only and the higher elongation required to effect force limiting by the webbing.

4. Additional work should be implemented to define and solve the 6 year old size problem with regard to adult restraint systems.

5. ATD model characteristics for sizes other than the 50th percentile are required for CVS simulations.

6. A methodology for obtaining the necessary dynamic input parameters for the CVS program should be developed.

7. Modification of the CVS III belt algorithm is required to include such things as user-specified belt friction options, multiple belt-segment contacts and the ability of the belt to slide.

8. Output options for the CVS III program should include terminet printing and CRT displays.

7.0 REFERENCES

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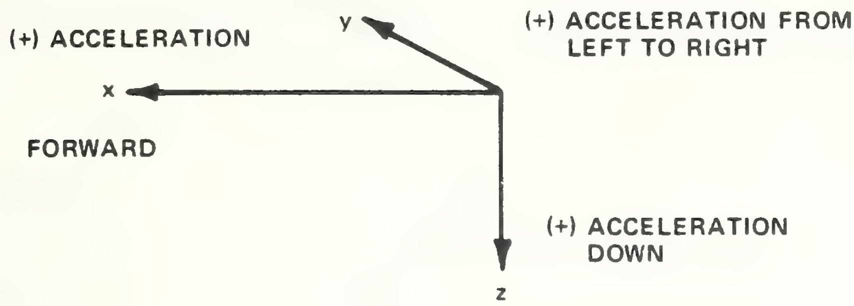
APPENDIX A

ON-LINE POLAROID PHOTOGRAPHS
AND DATA TRACES

Time history graphs from the sled tests are presented in Appendix A. These raw data graphs are identified by facility run number. All performance evaluation graphs have been filtered at the proper channel class according to the requirements of FMVSS 208. The time trace on the bottom of each page is displayed in 10 ms. divisions. The scales on each data trace are indicated by the total value between arrows. Identification of the individual channels is as follows:

H_X	=	Head G_X
H_Y	=	Head G_Y
H_Z	=	Head G_Z
H_R	=	Head G_R
HSI	=	Head Severity Index
C_X	=	Chest G_X
C_Y	=	Chest G_Y
C_Z	=	Chest G_Z
C_R	=	Chest G_R
CSI	=	Chest Severity Index
L. FEM	=	Left Femur Compressive Load in Pounds
R. FEM	=	Right Femur Compressive Load in Pounds
Sled	=	Sled G_X
U SH	=	Upper Shoulder Strap Load in Pounds
L LAP	=	Lower Shoulder Strap Load in Pounds
R LAP	=	Lap Belt Load in Pounds
D-ring	=	ELR to D-ring Load in Pounds
P_X	=	Pelvis G_X
P_Y	=	Pelvis G_Y
P_Z	=	Pelvis G_Z
P_R	=	Pelvis G_R

The sign convention used on these tests is presented below.



ACCELERATION SIGN CONVENTION

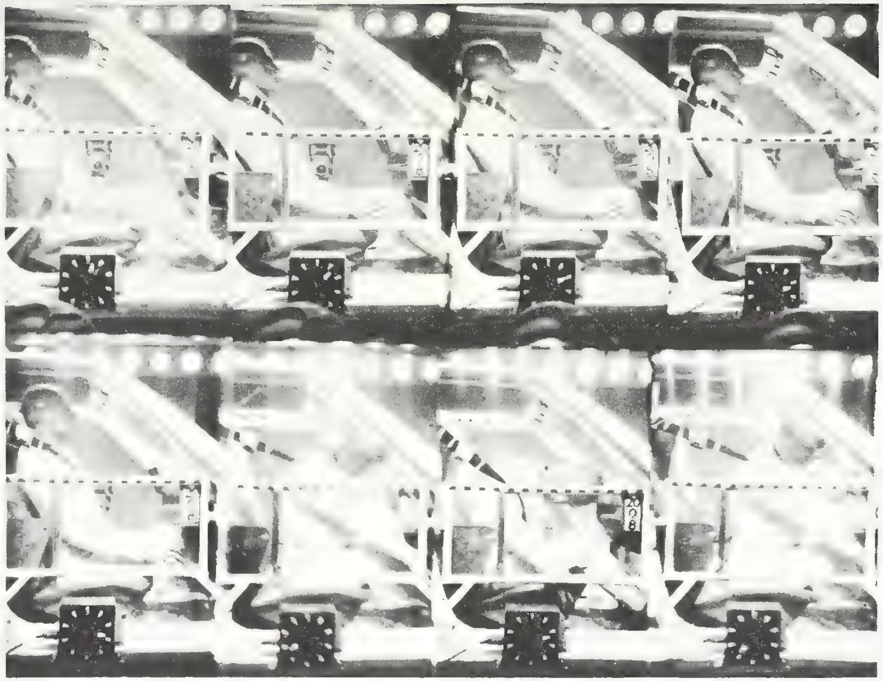
(1) Vehicle and dummy accelerations agree with above convention

(2) Webbing load - tension is positive
Femur loads - compression is positive

INDEX TO APPENDIX A

ON-LINE POLAROID PHOTOGRAPHS AND DATA TRACES

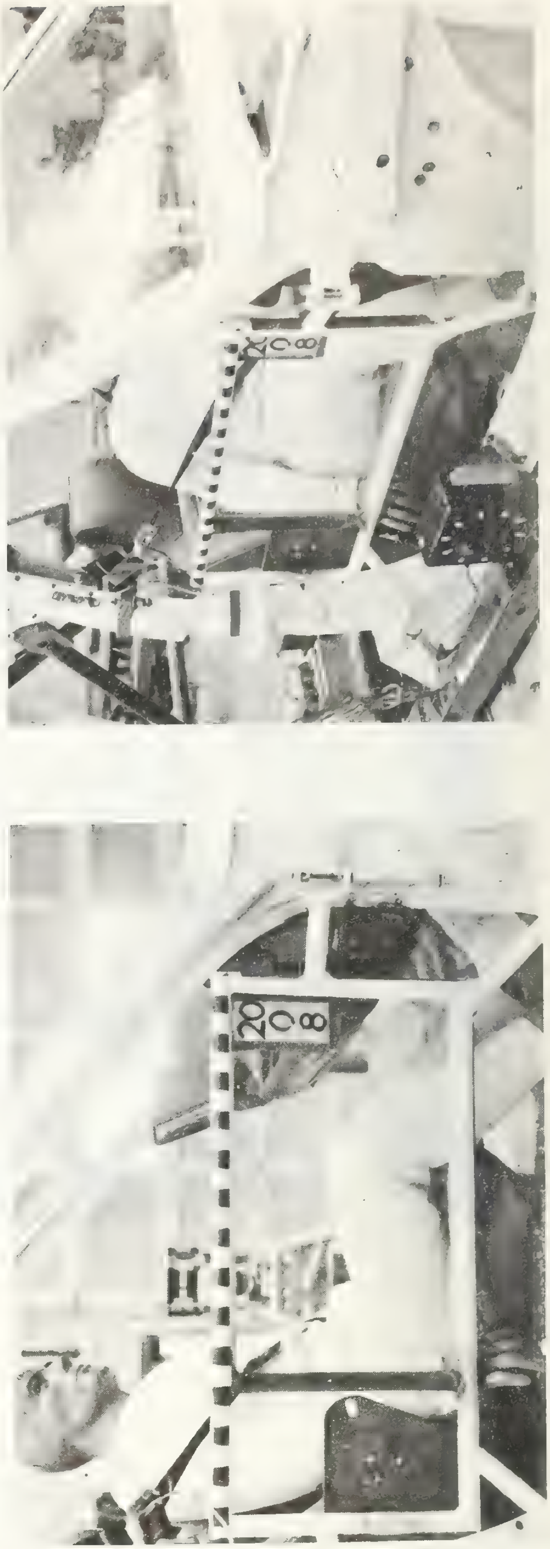
1 2 3 4



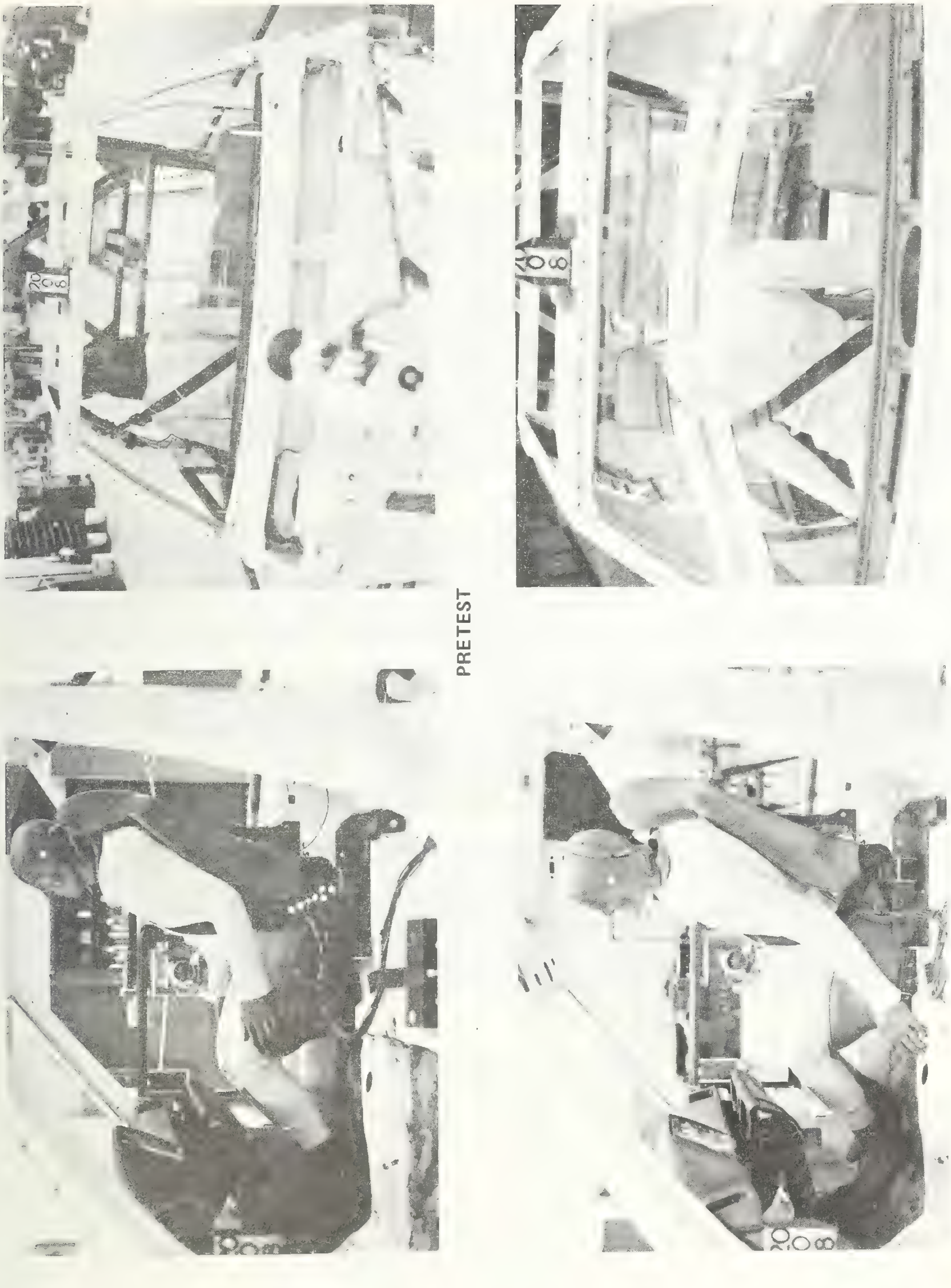
5 7 8 6

RUN 2008 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

PRETEST



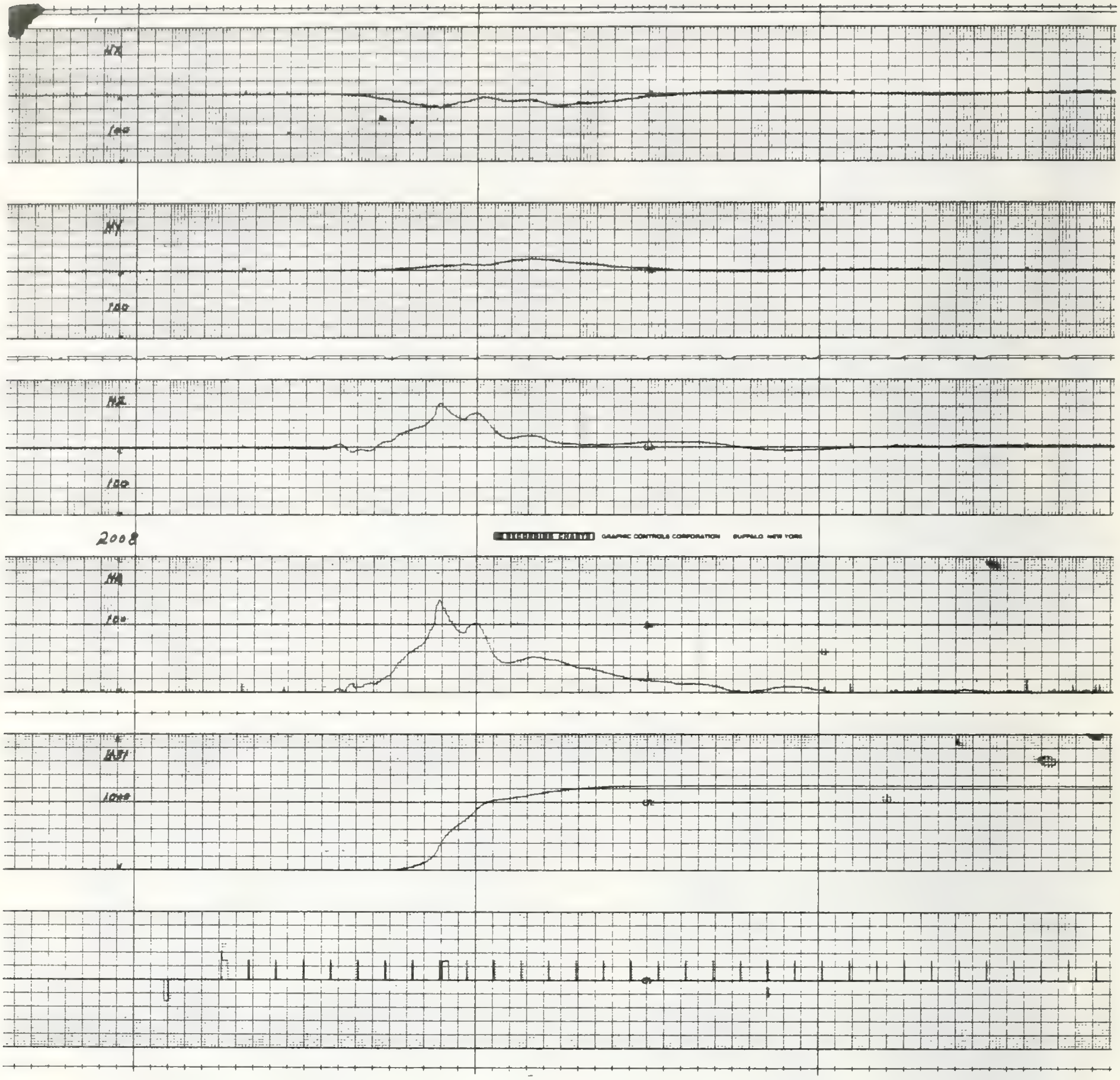
POST TEST
RUN 2008



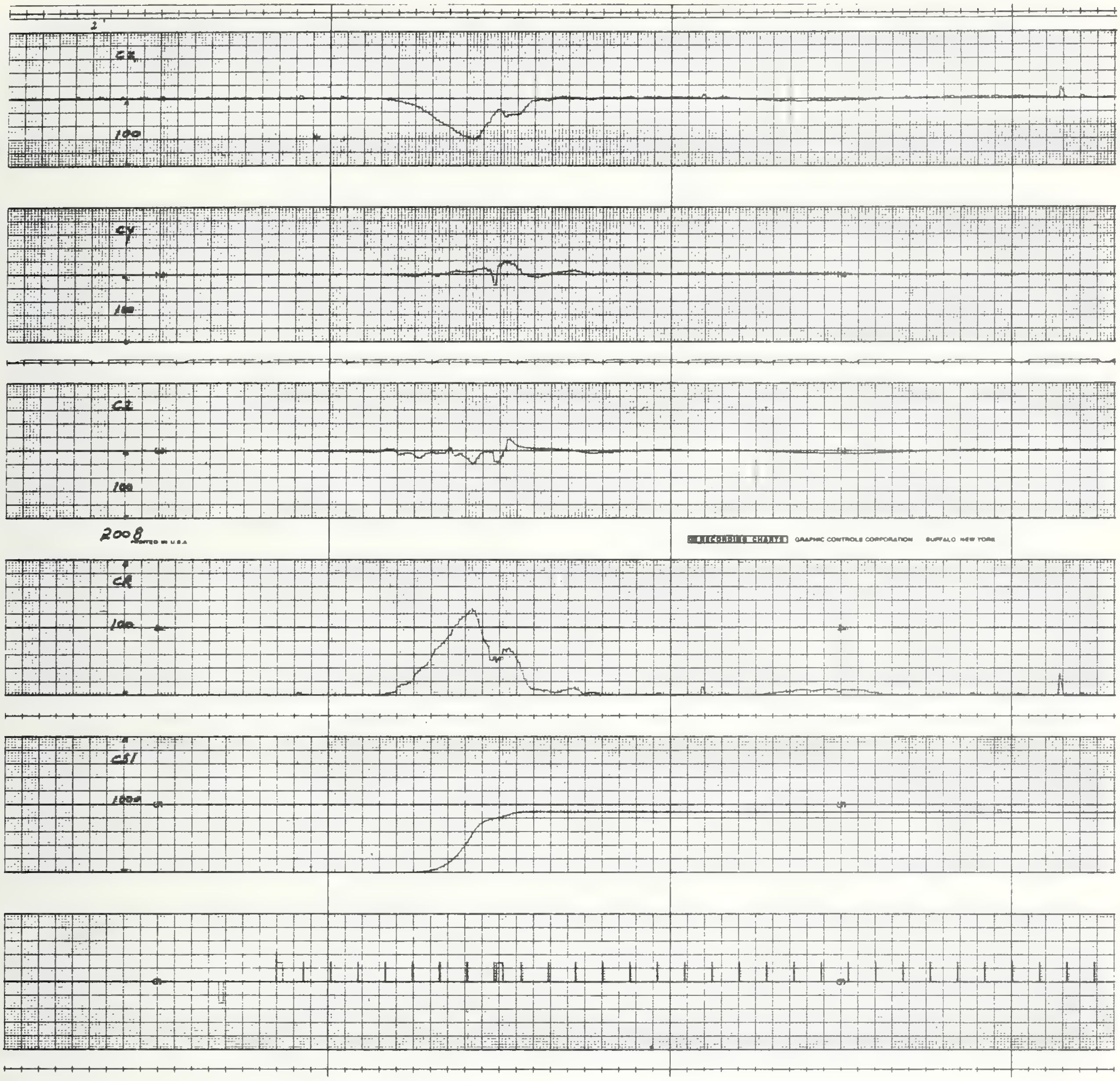
PRETEST

POST TEST

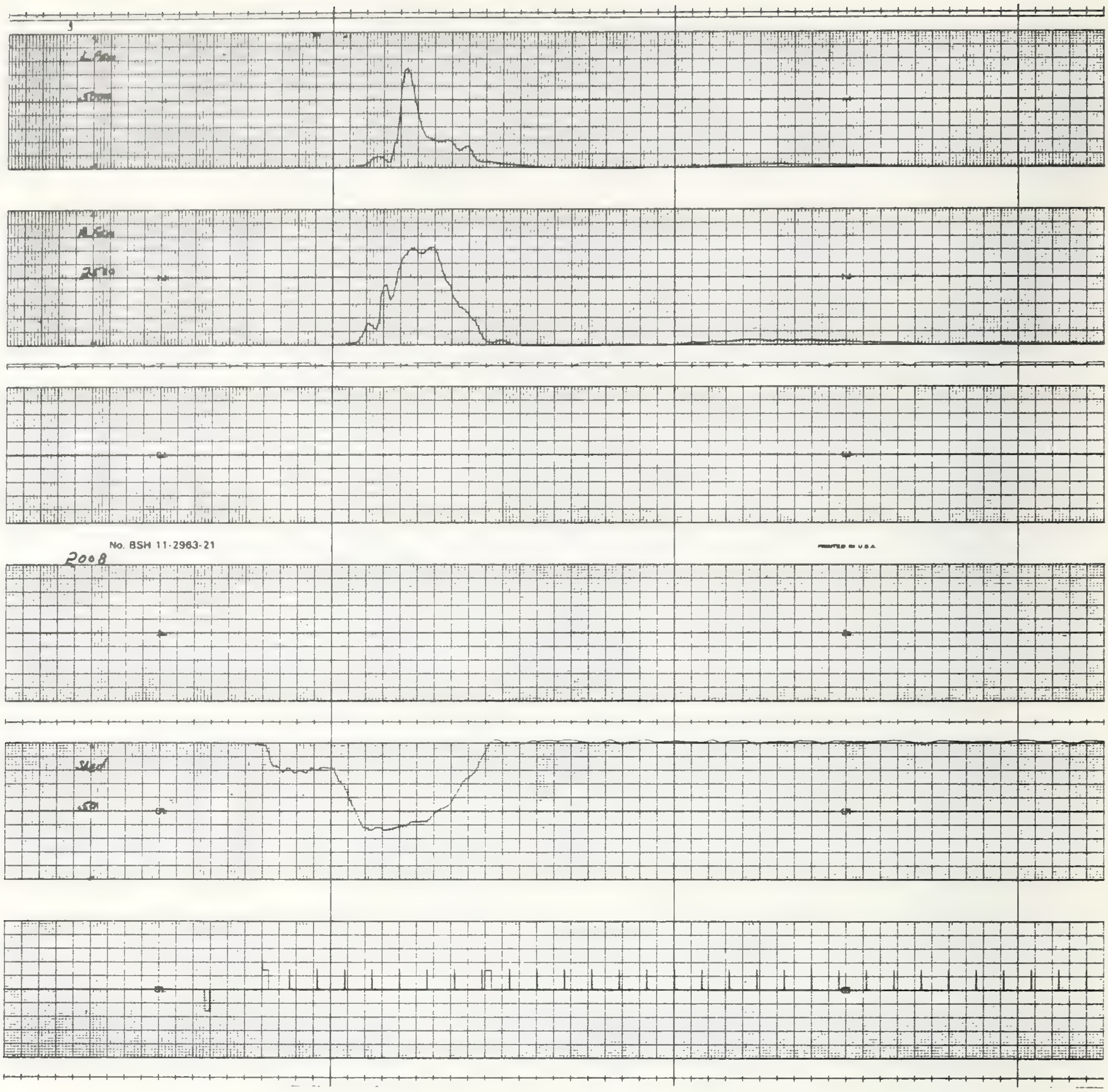
RUN 2008



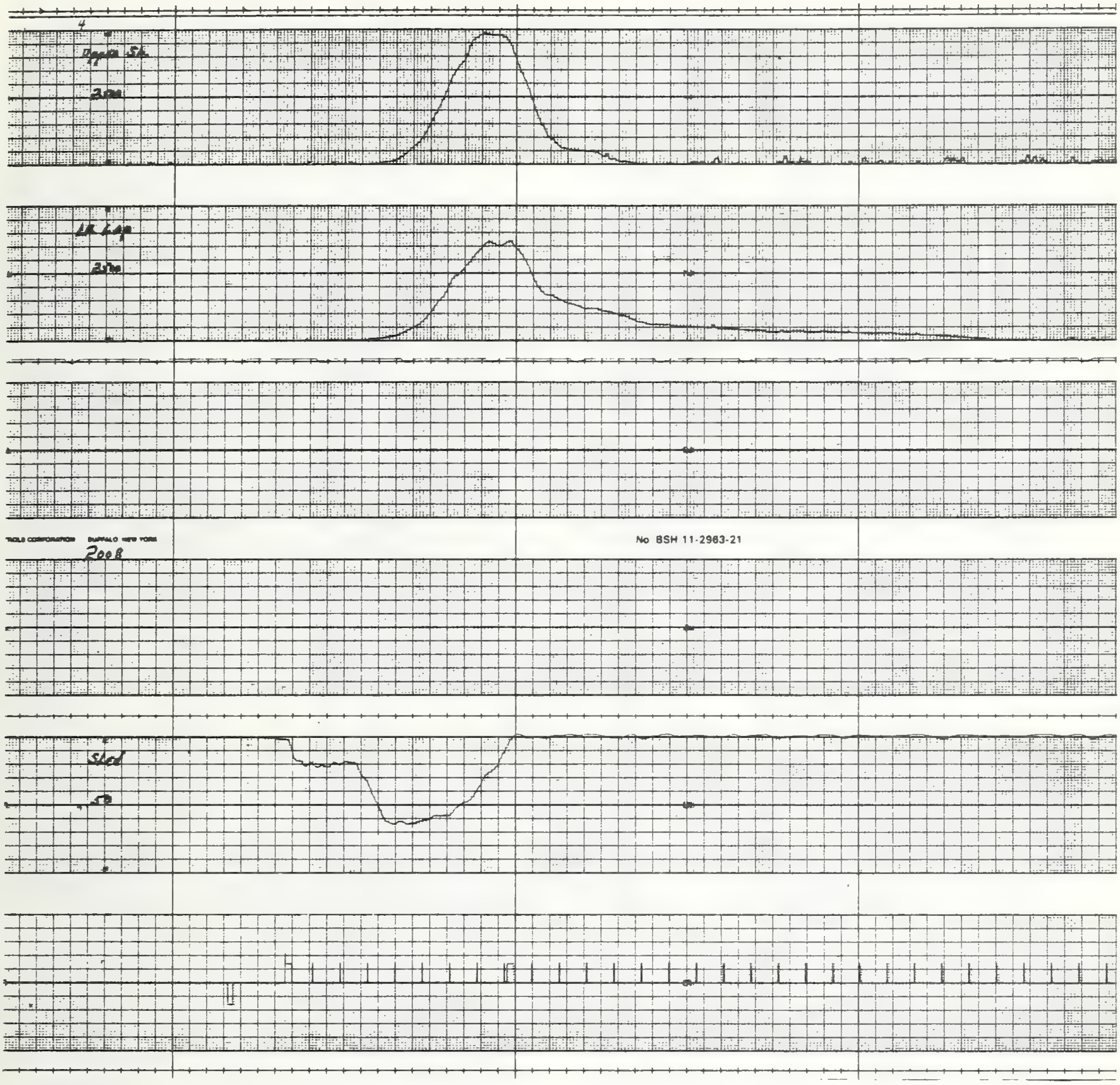
Time = 10 ms/division



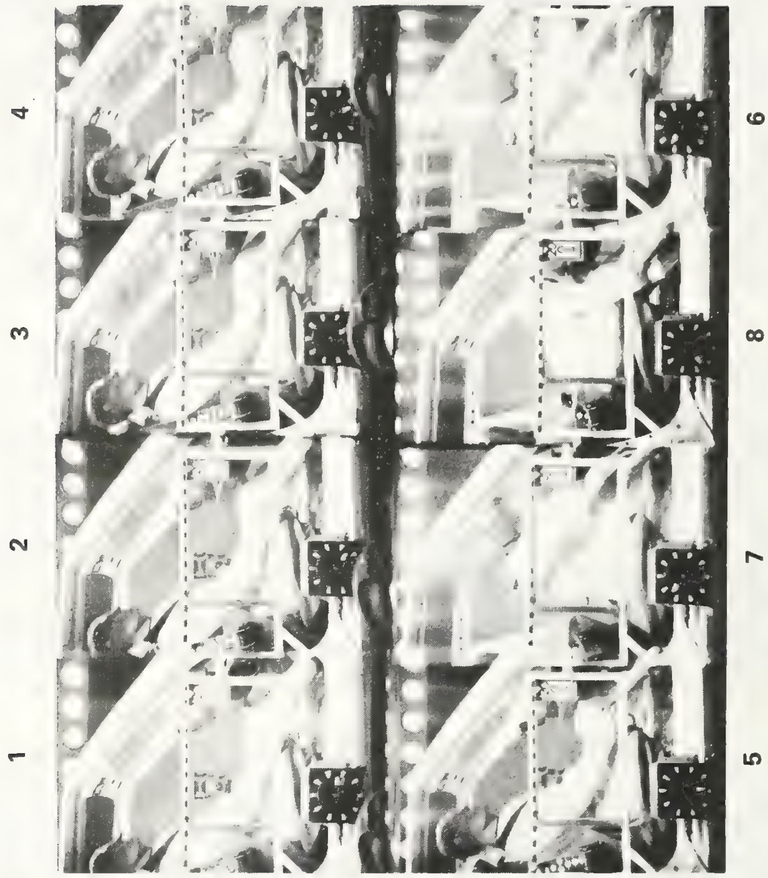
Time = 10 ms/division



Time = 10 ms/division

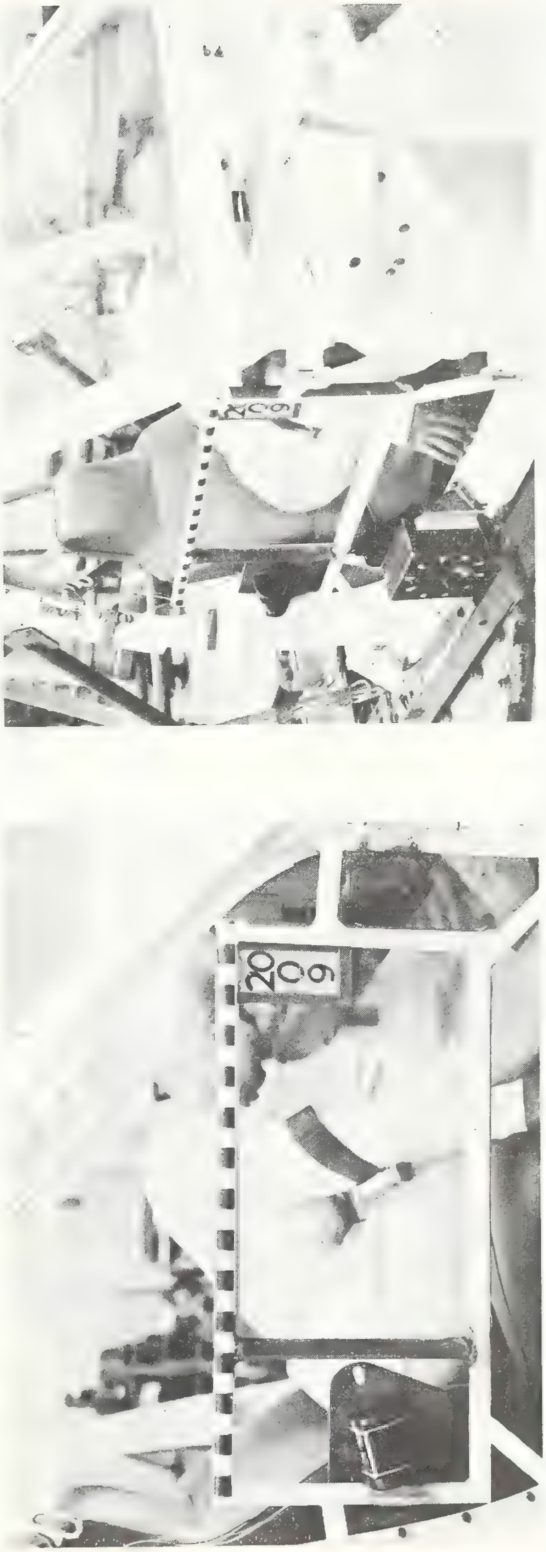


Time = 10 ms/division



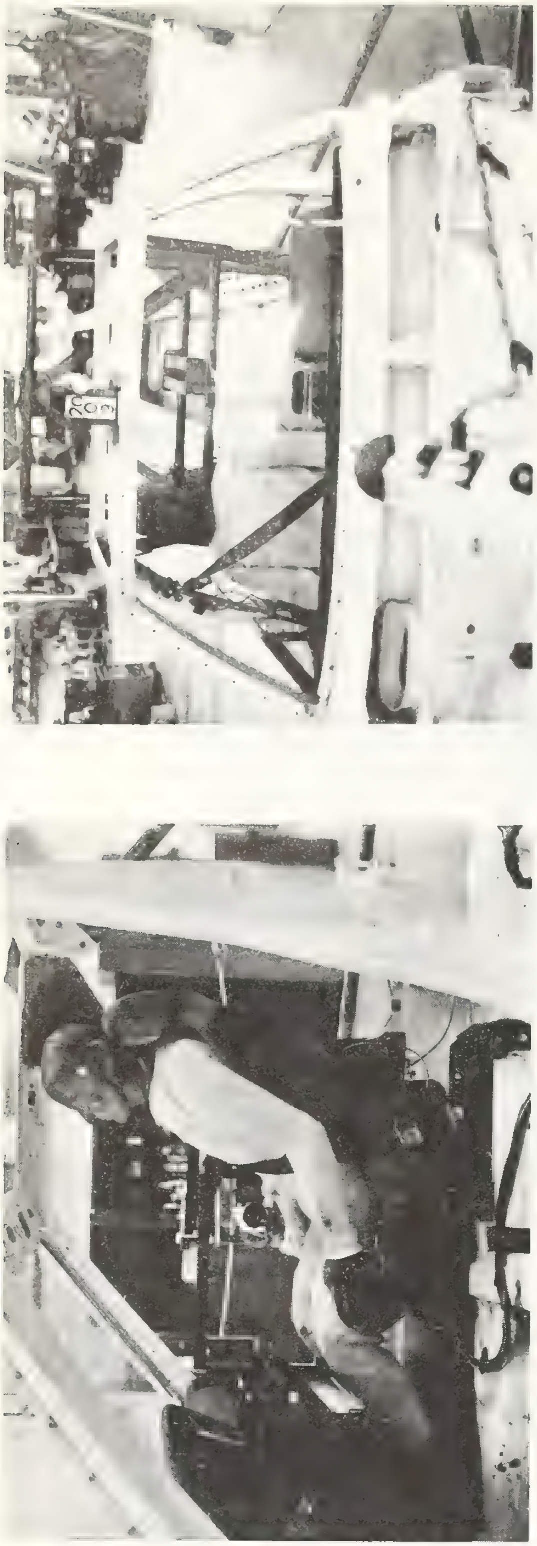
RUN 2009 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

PRETEST

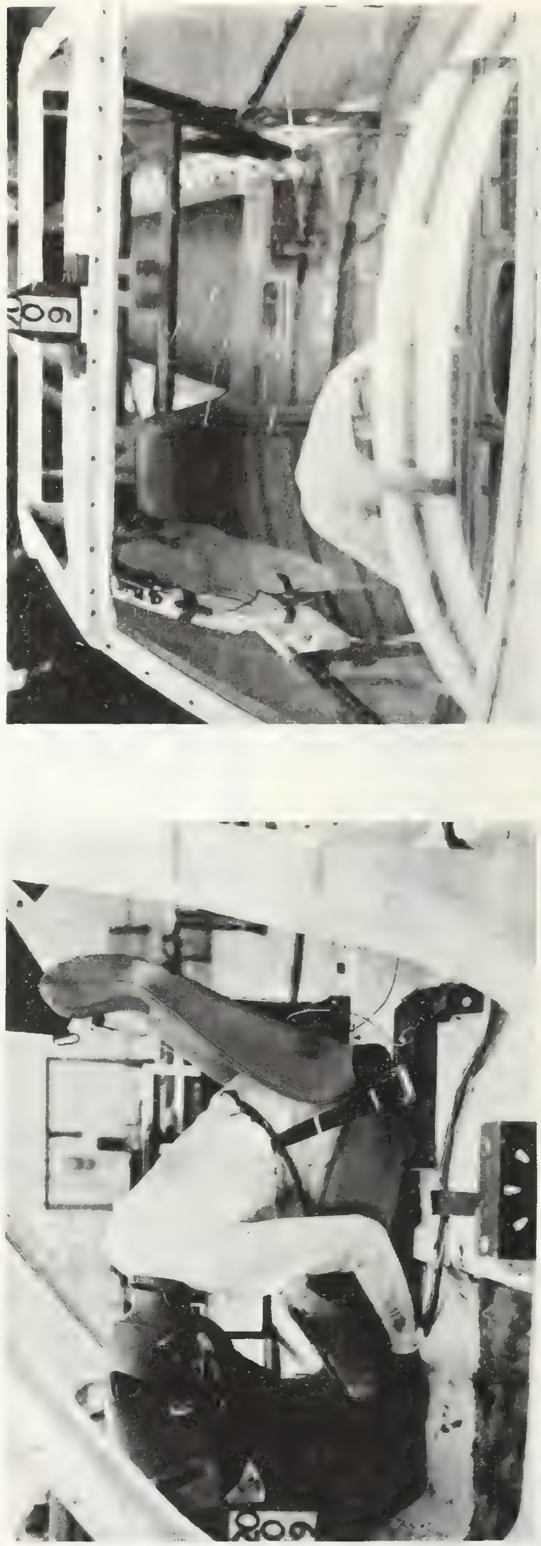


POST TEST

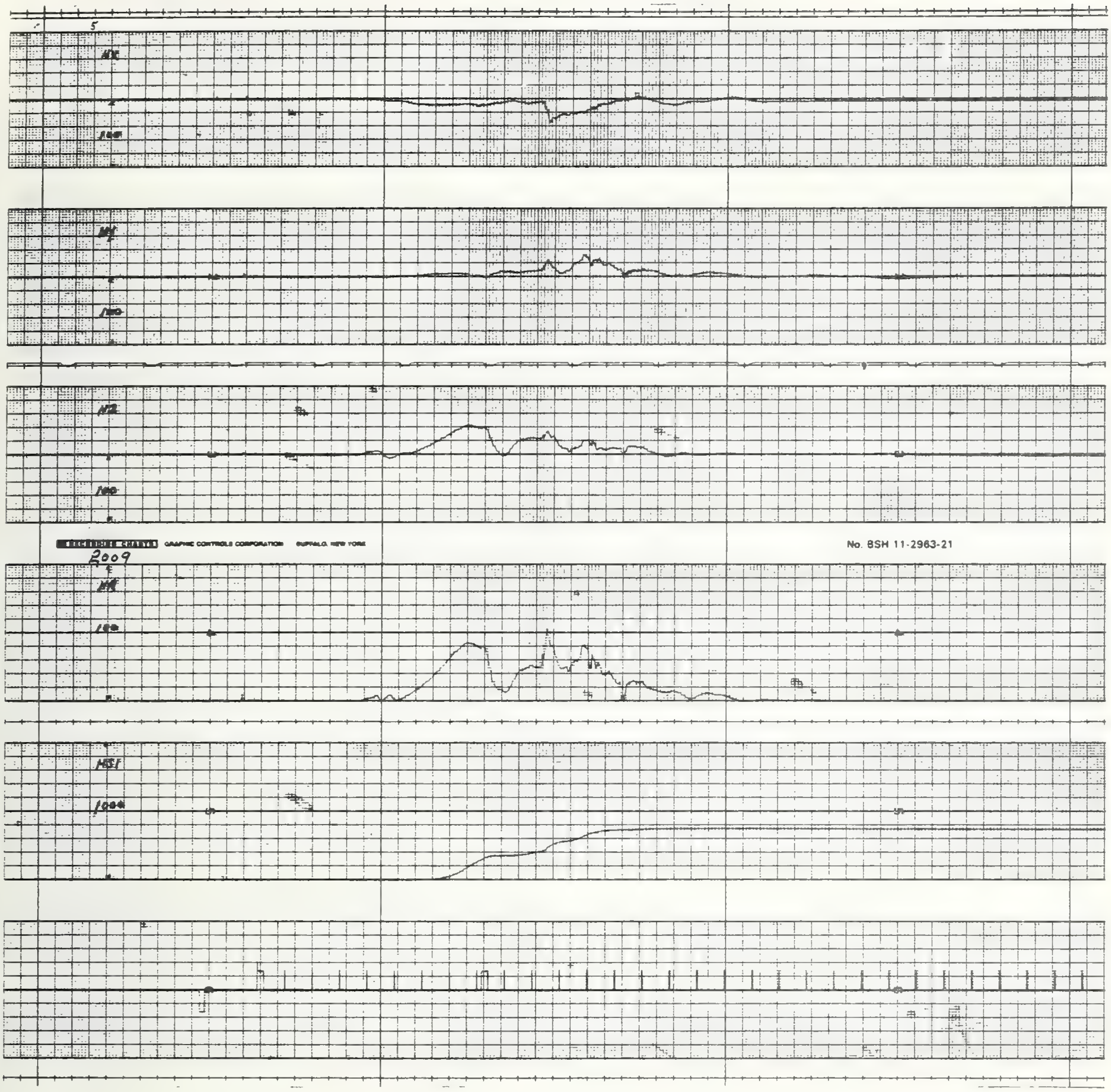
RUN 2009



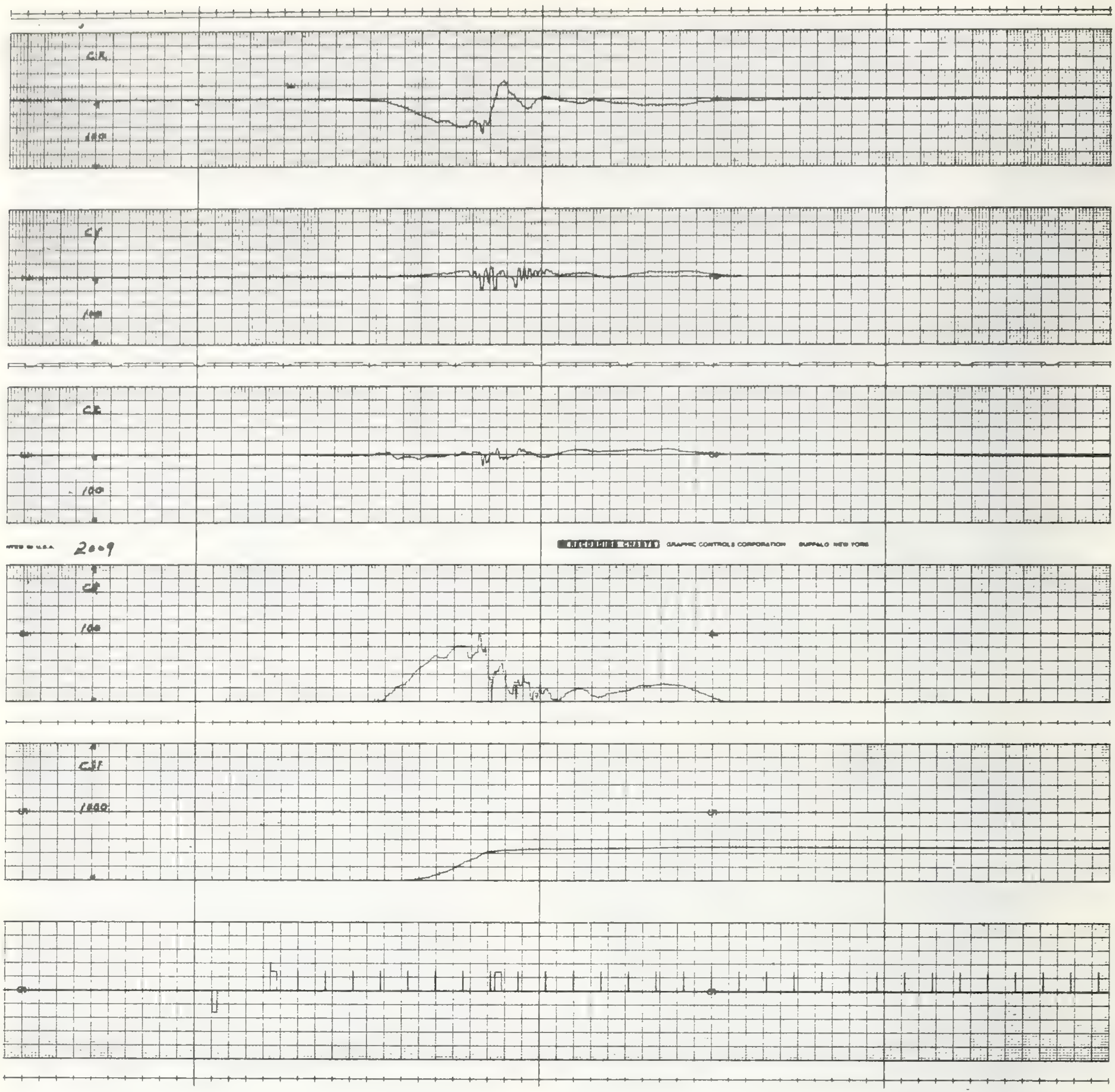
PRETEST



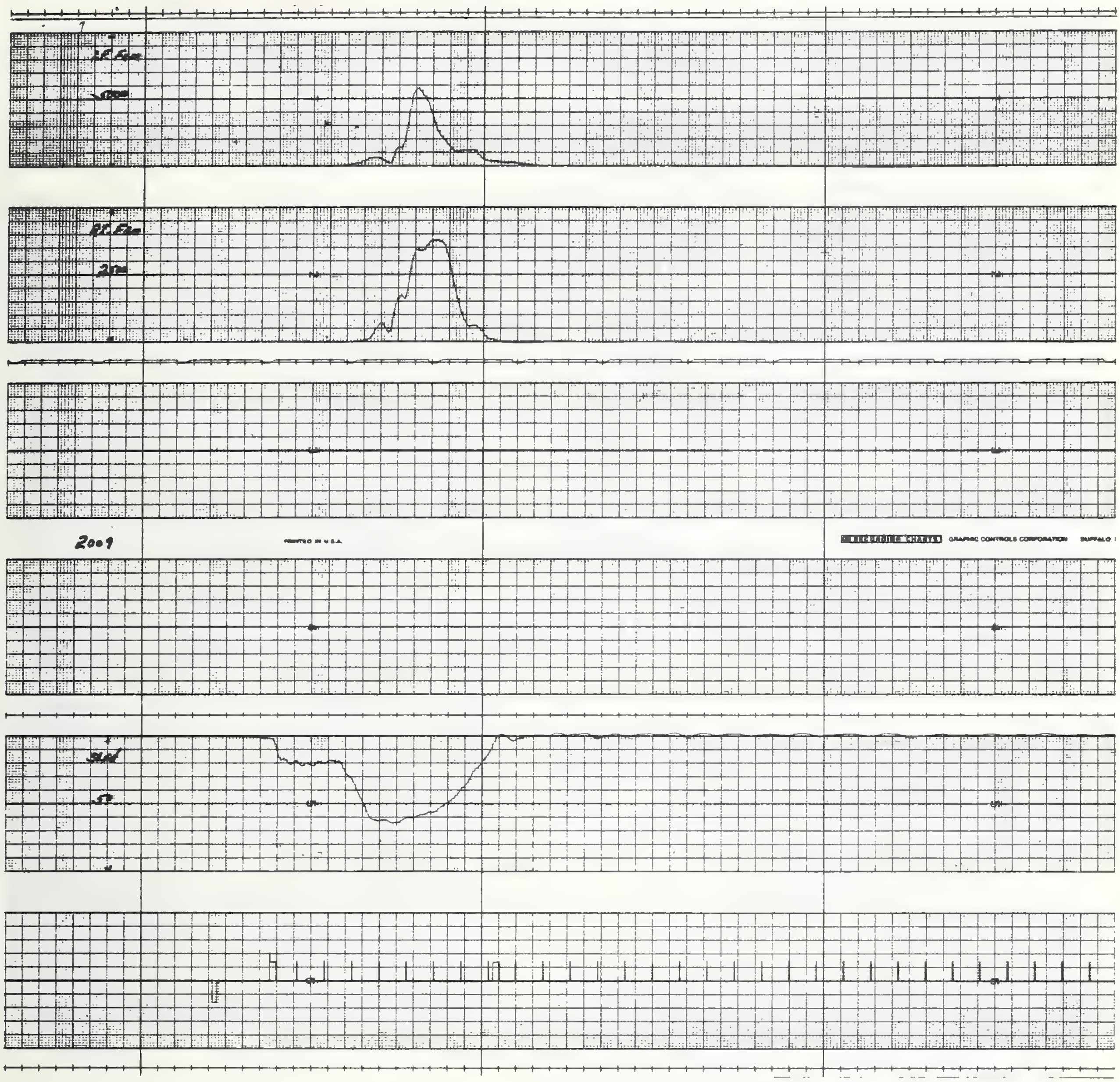
POST TEST
RUN 2009



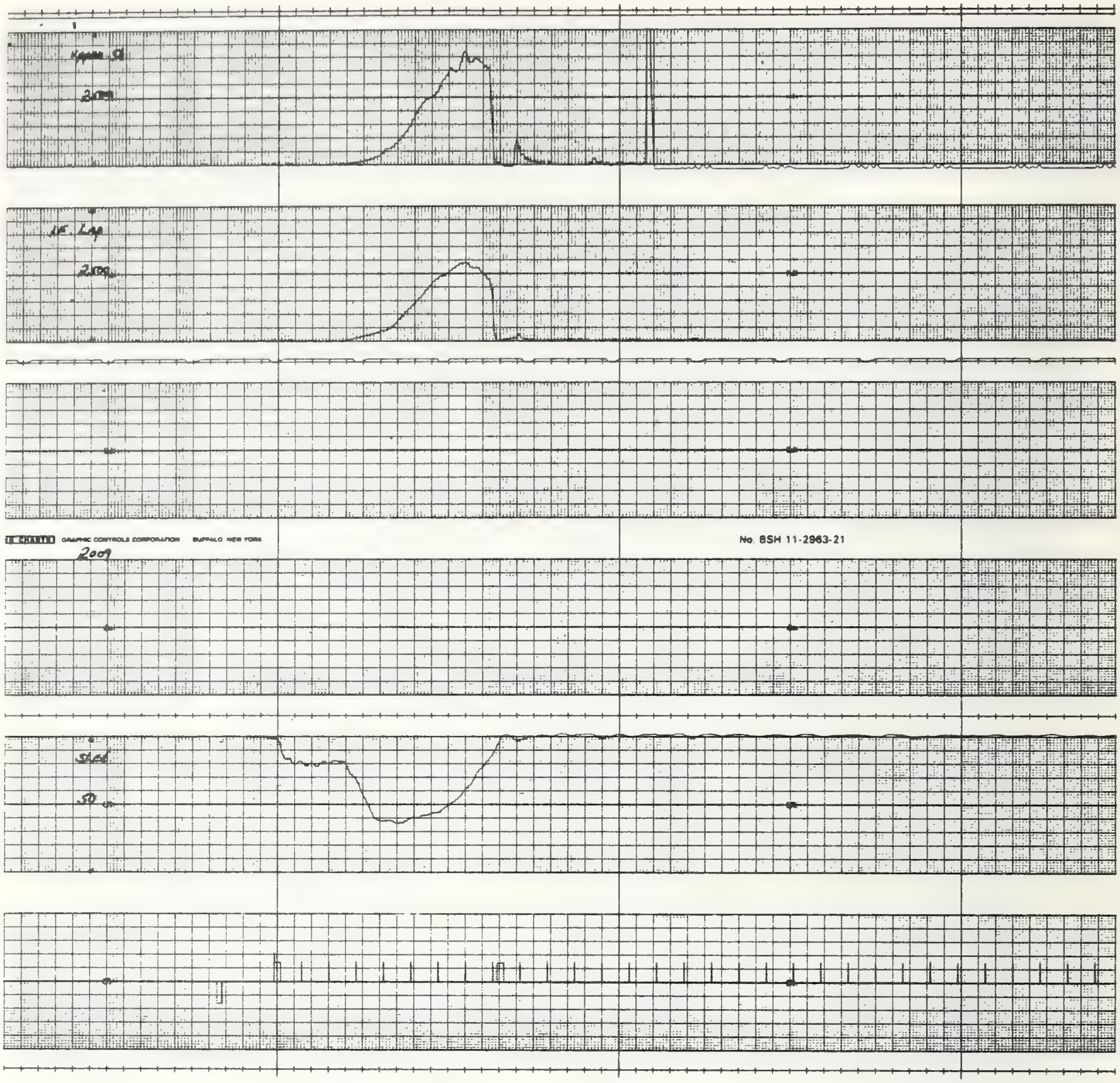
Time = 10 ms/division



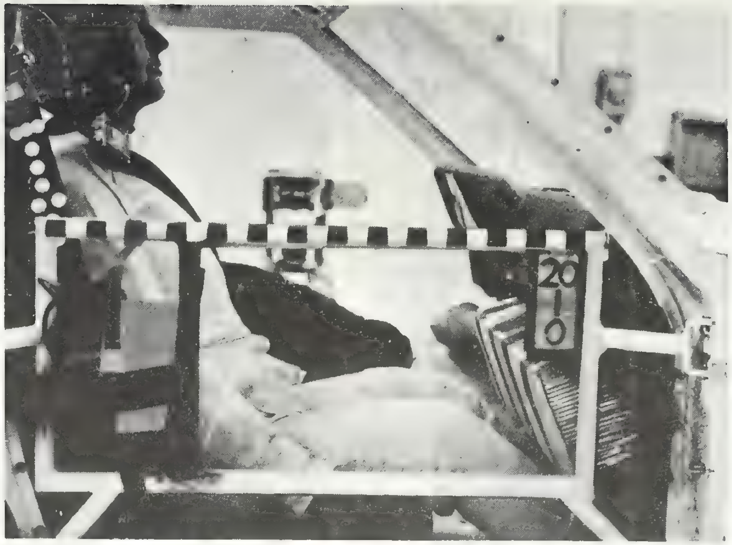
Time = 10 ms/division



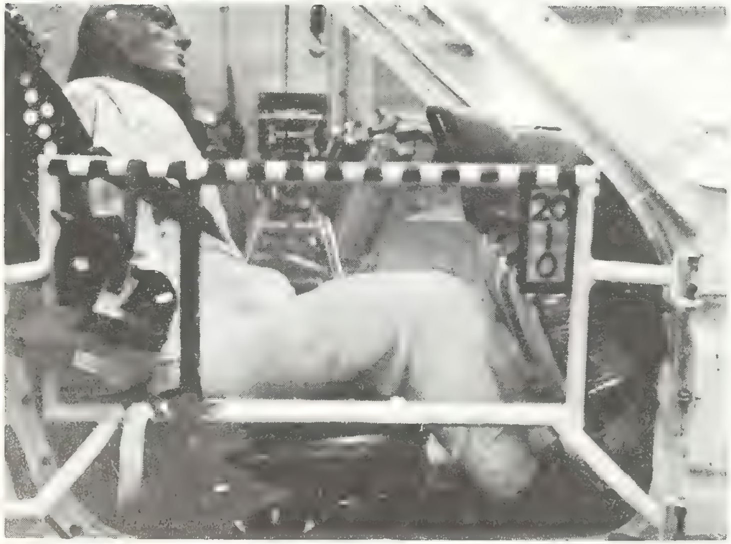
Time = 10 ms/division

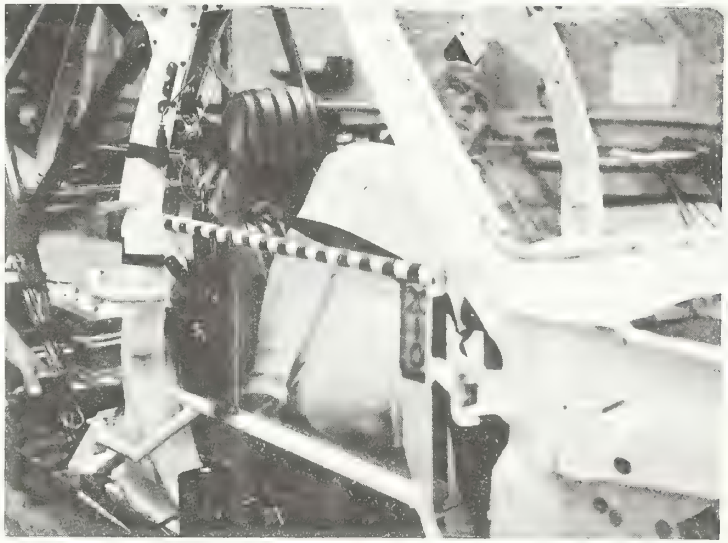


Time = 10 ms/division



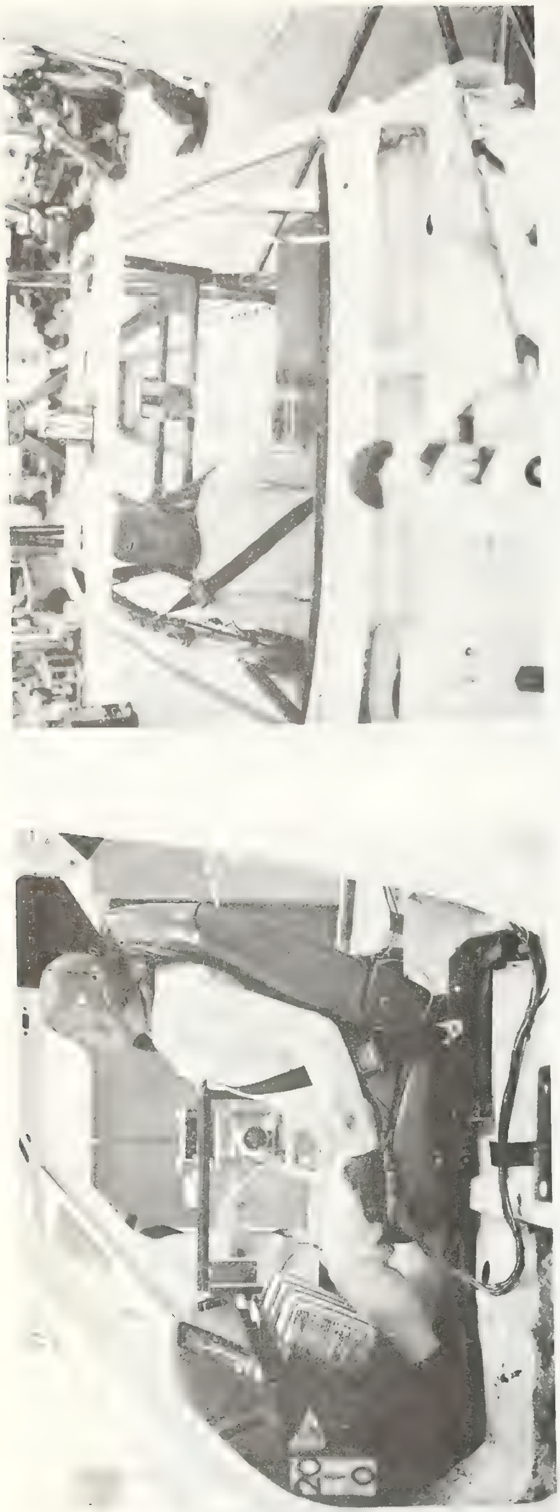
PRETEST





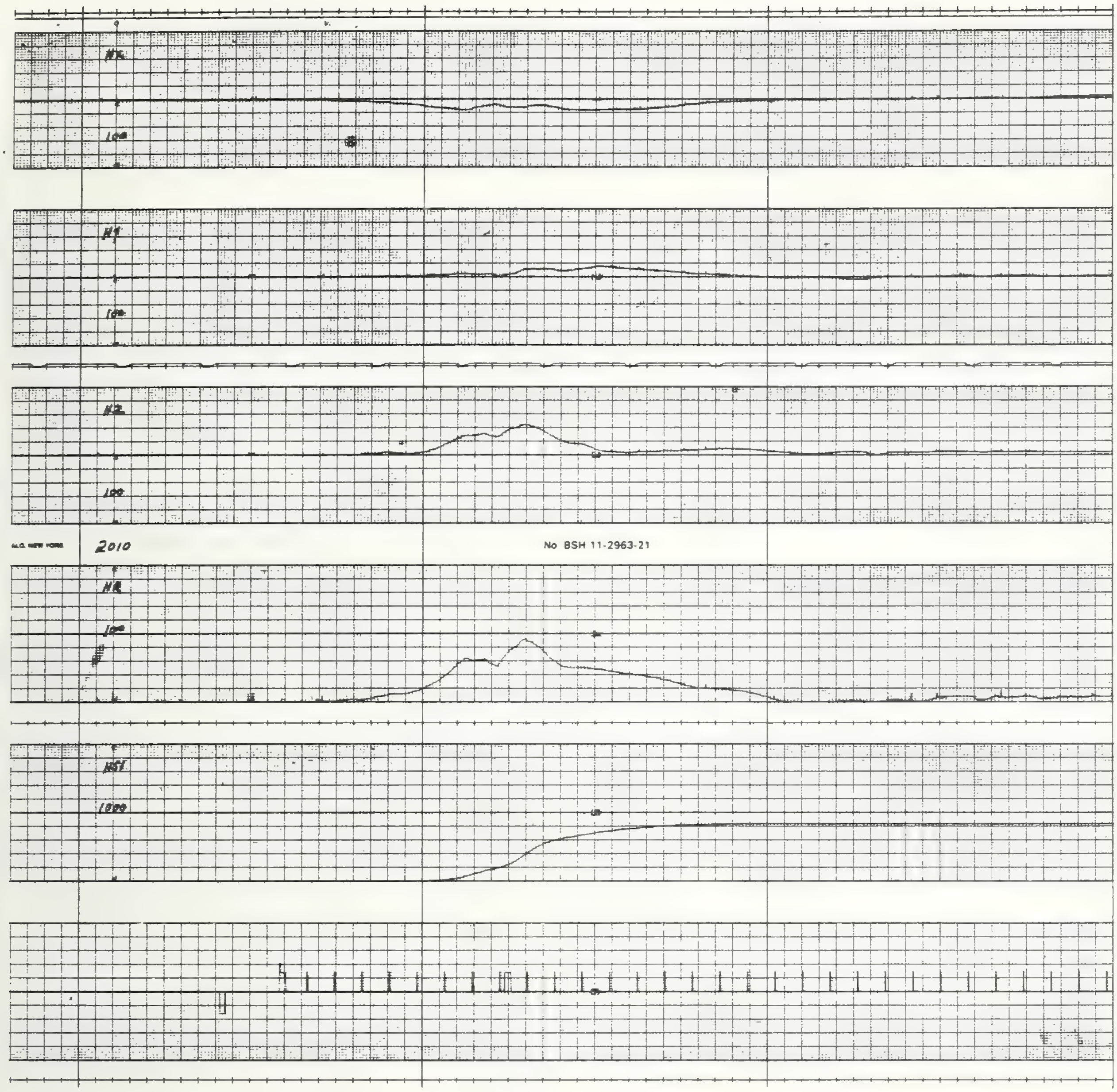
POST TEST

RUN 2010

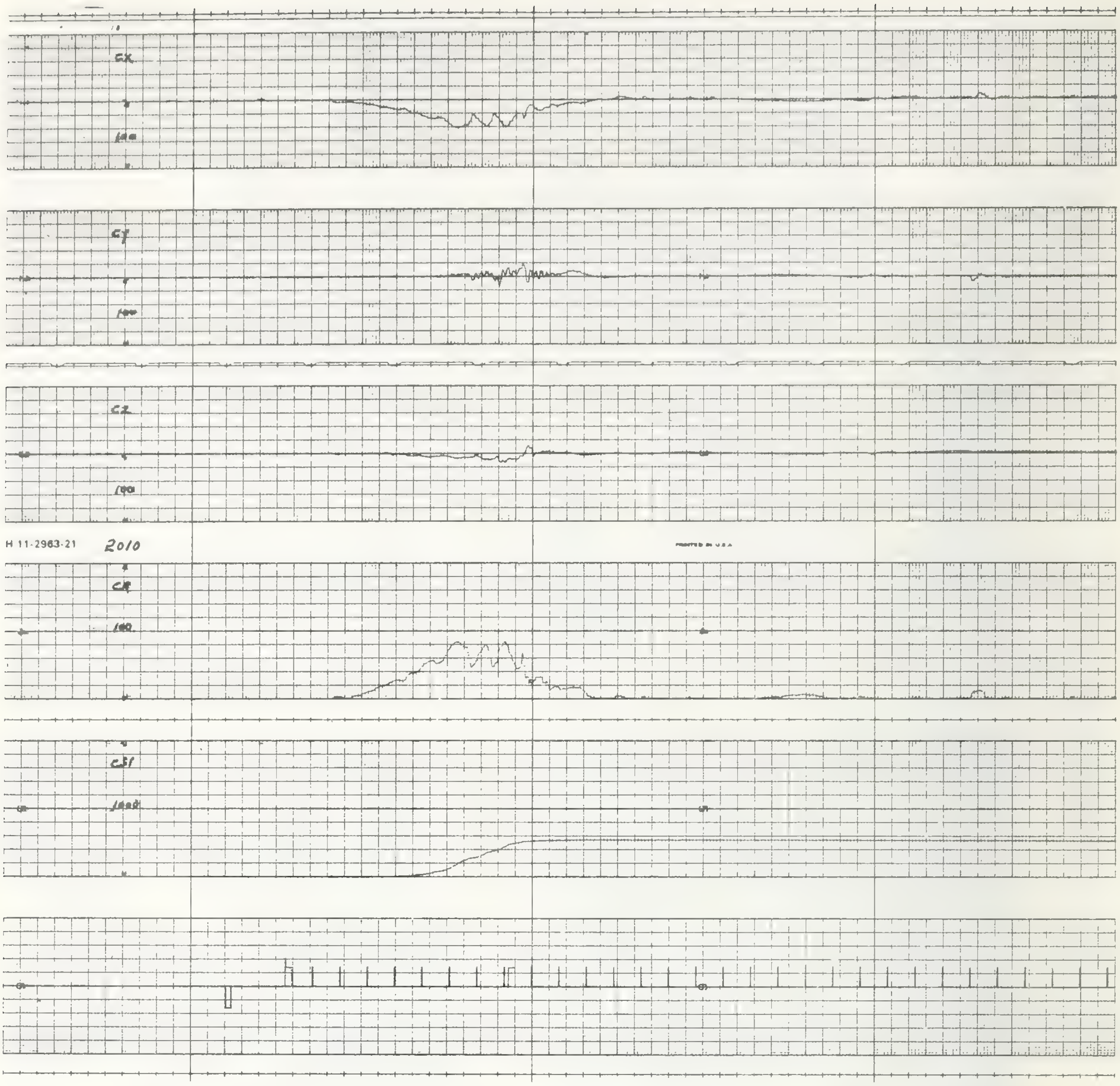


PRETEST

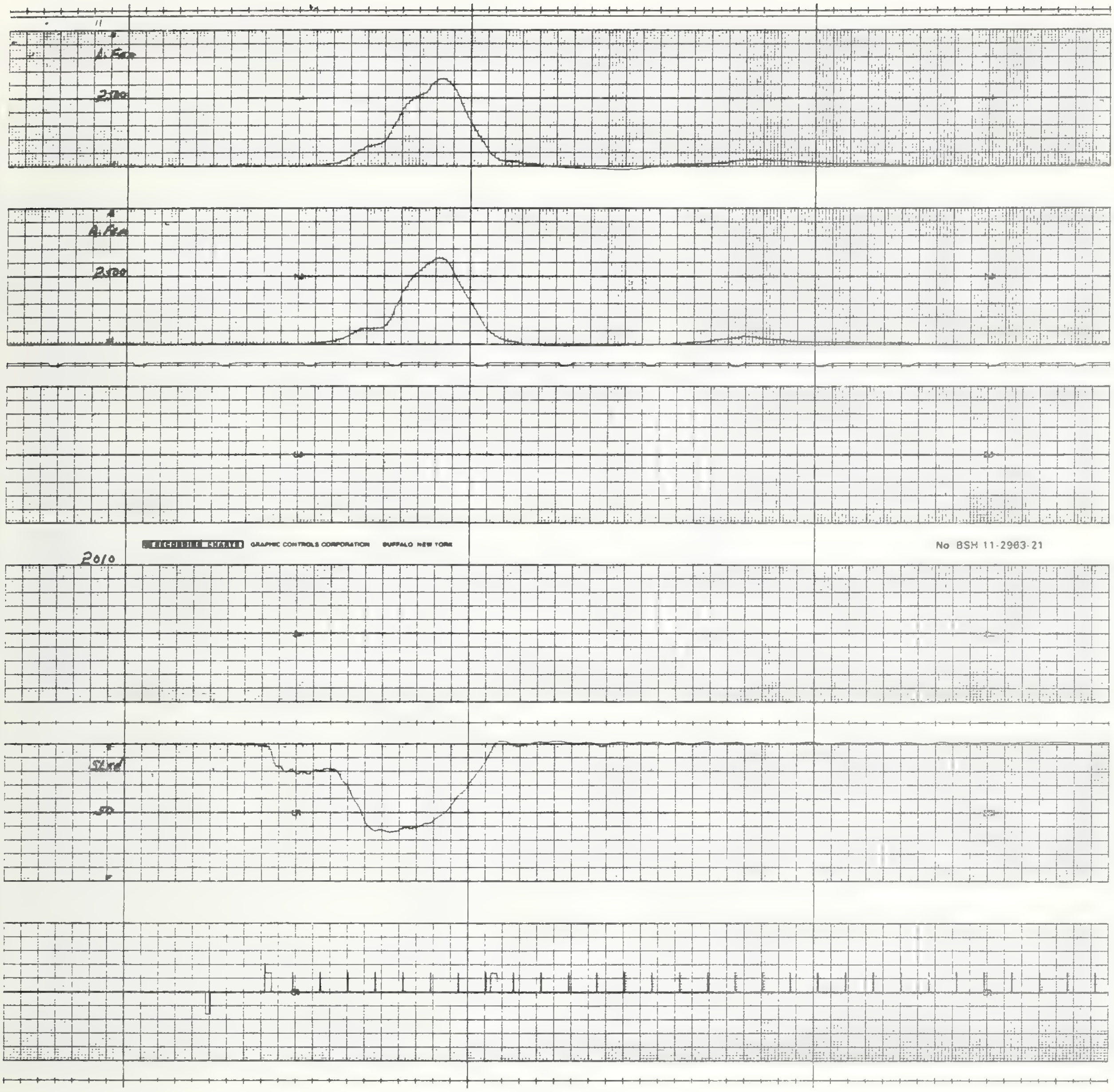
POST TEST
RUN 2010



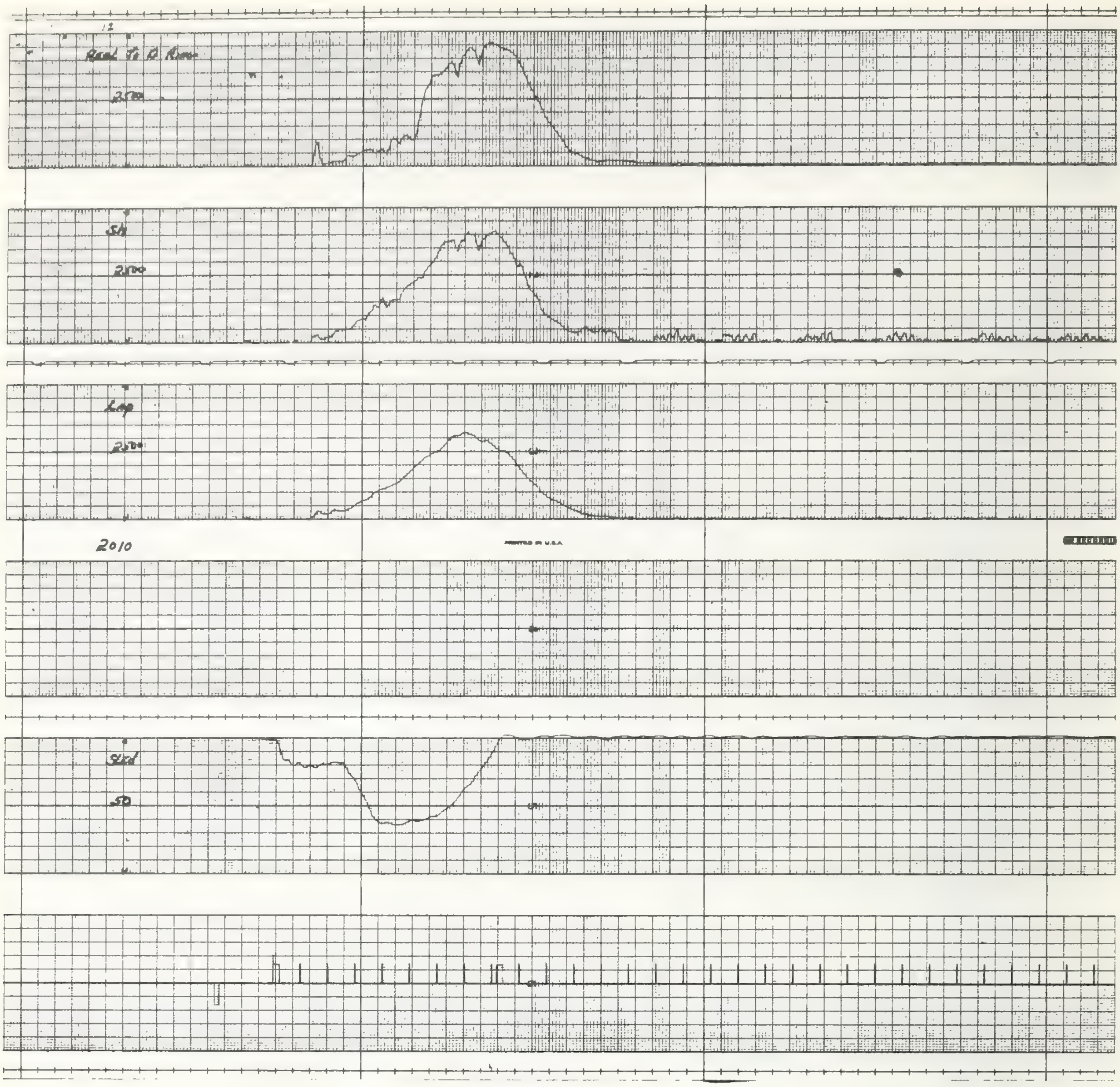
Time = 10 ms/division



Time = 10 ms/division

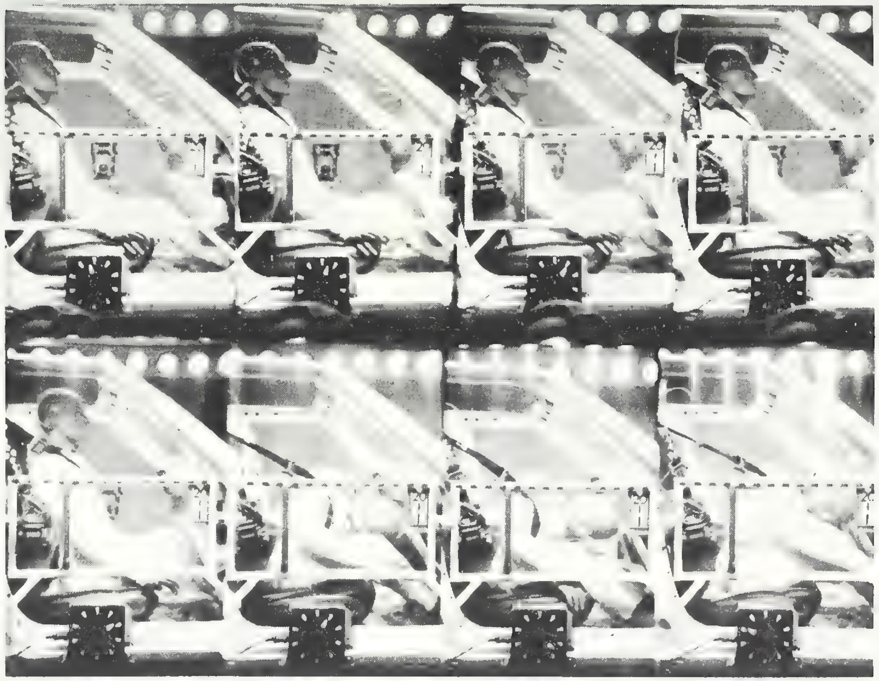


Time = 10 ms/division



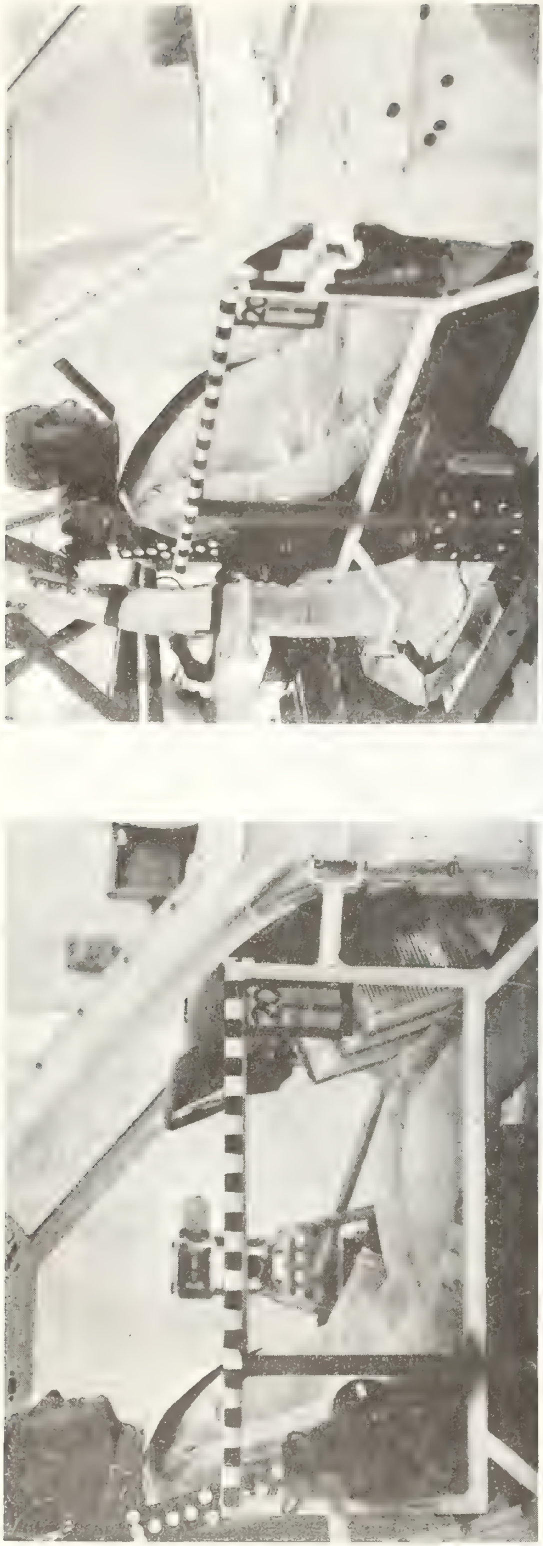
Time = 10 ms/division

1 2 3 4

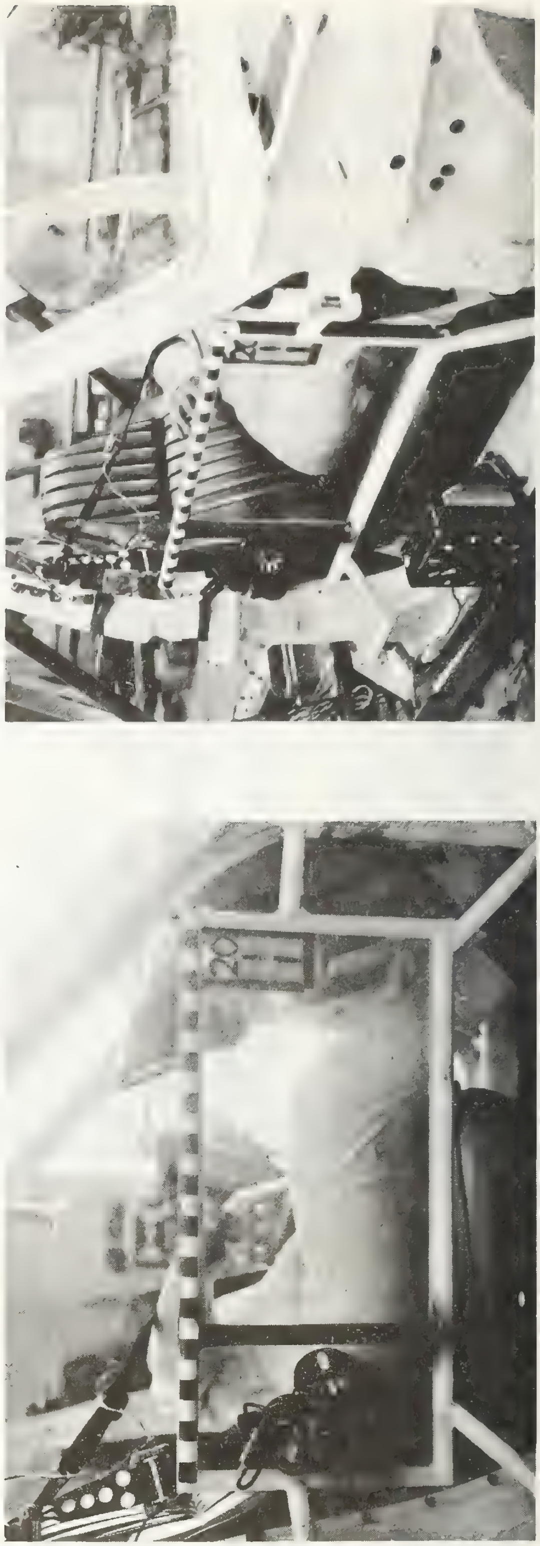


5 7 8 6

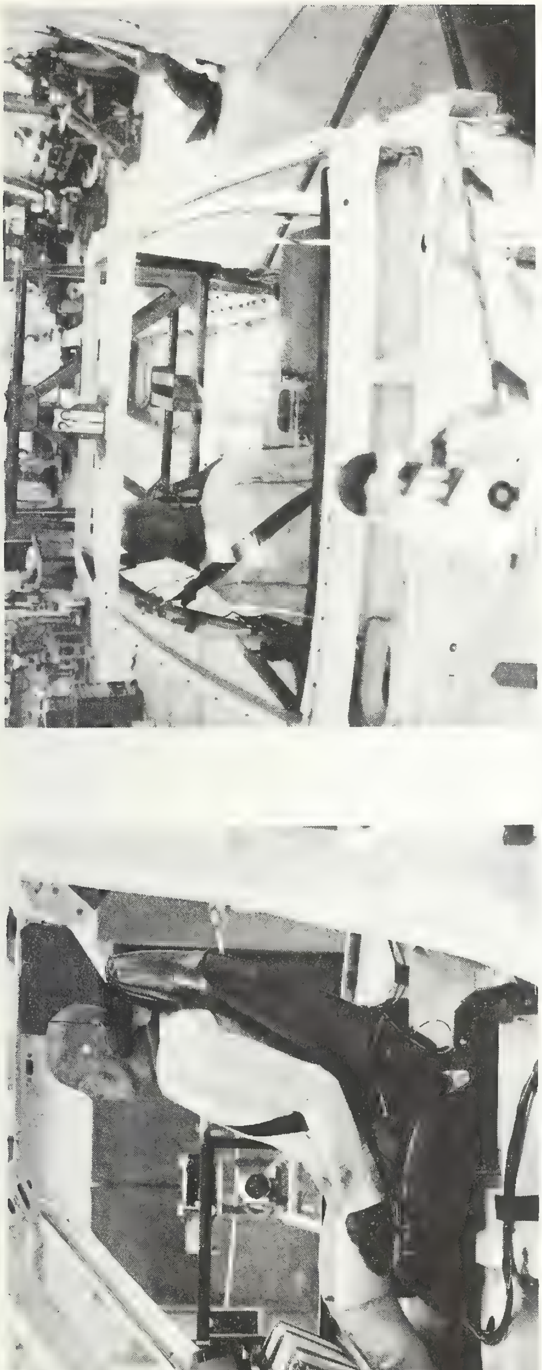
RUN 2011 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION



PRETEST

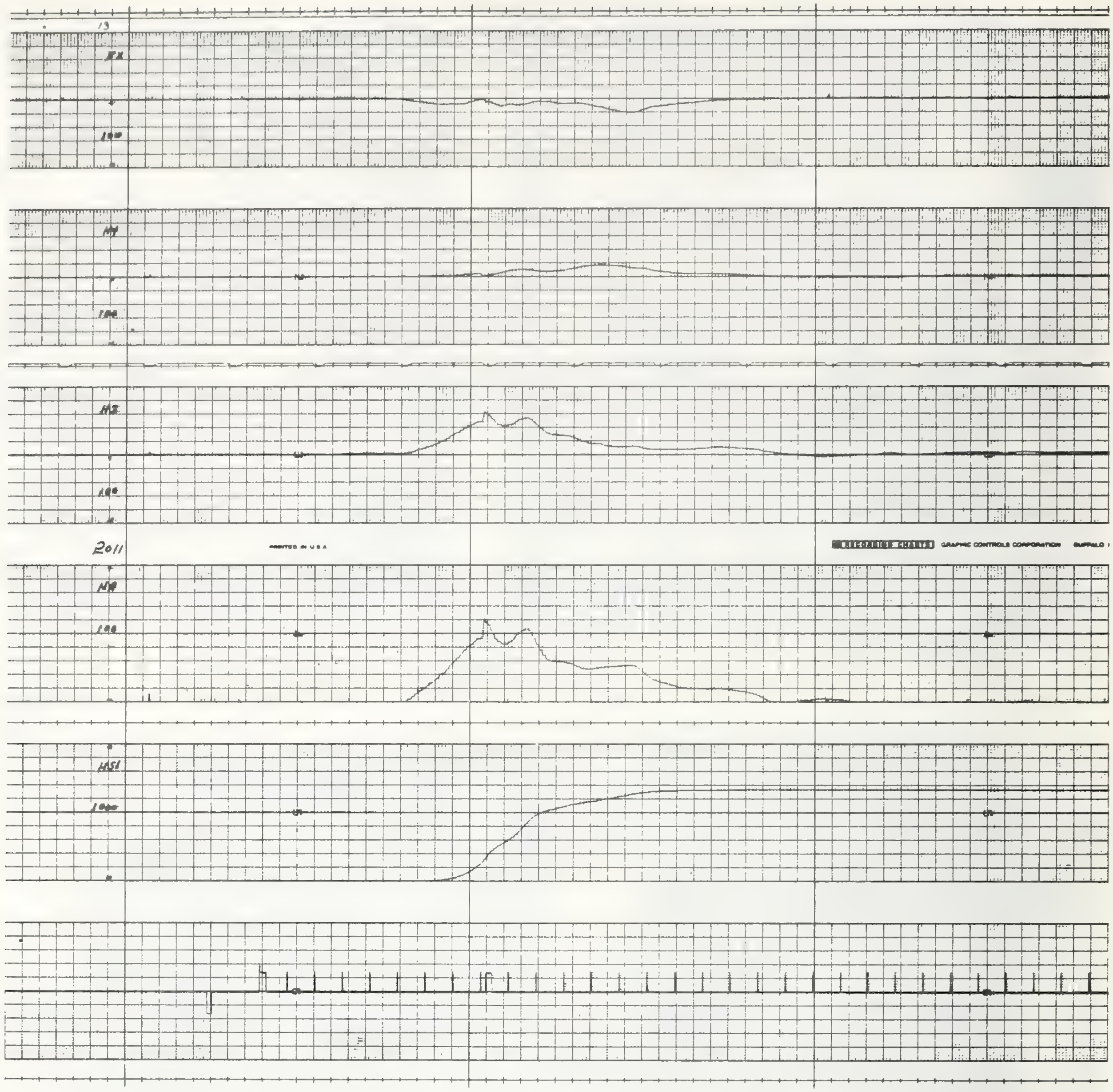


POST TEST
RUN 2011

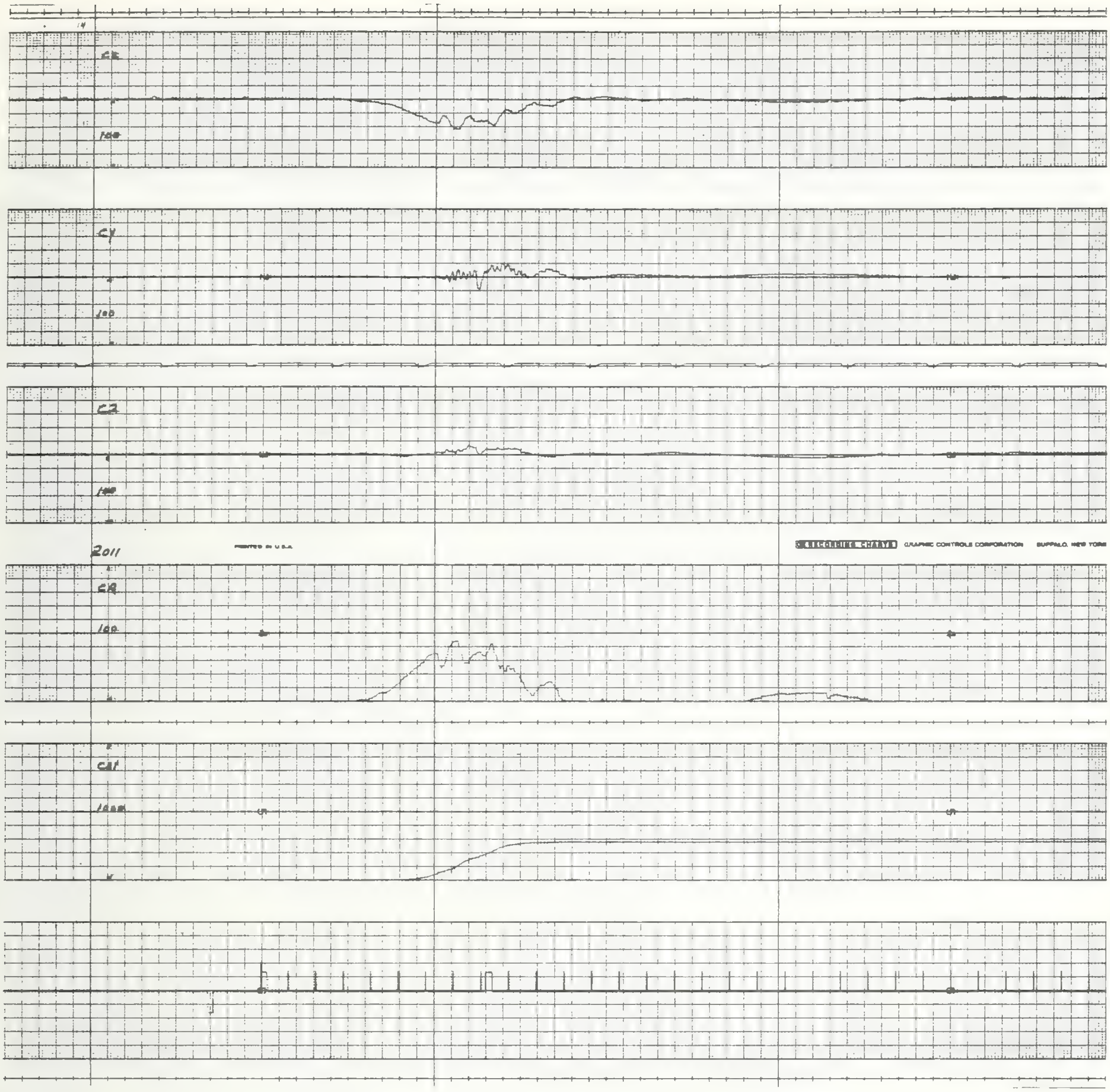


PRETEST

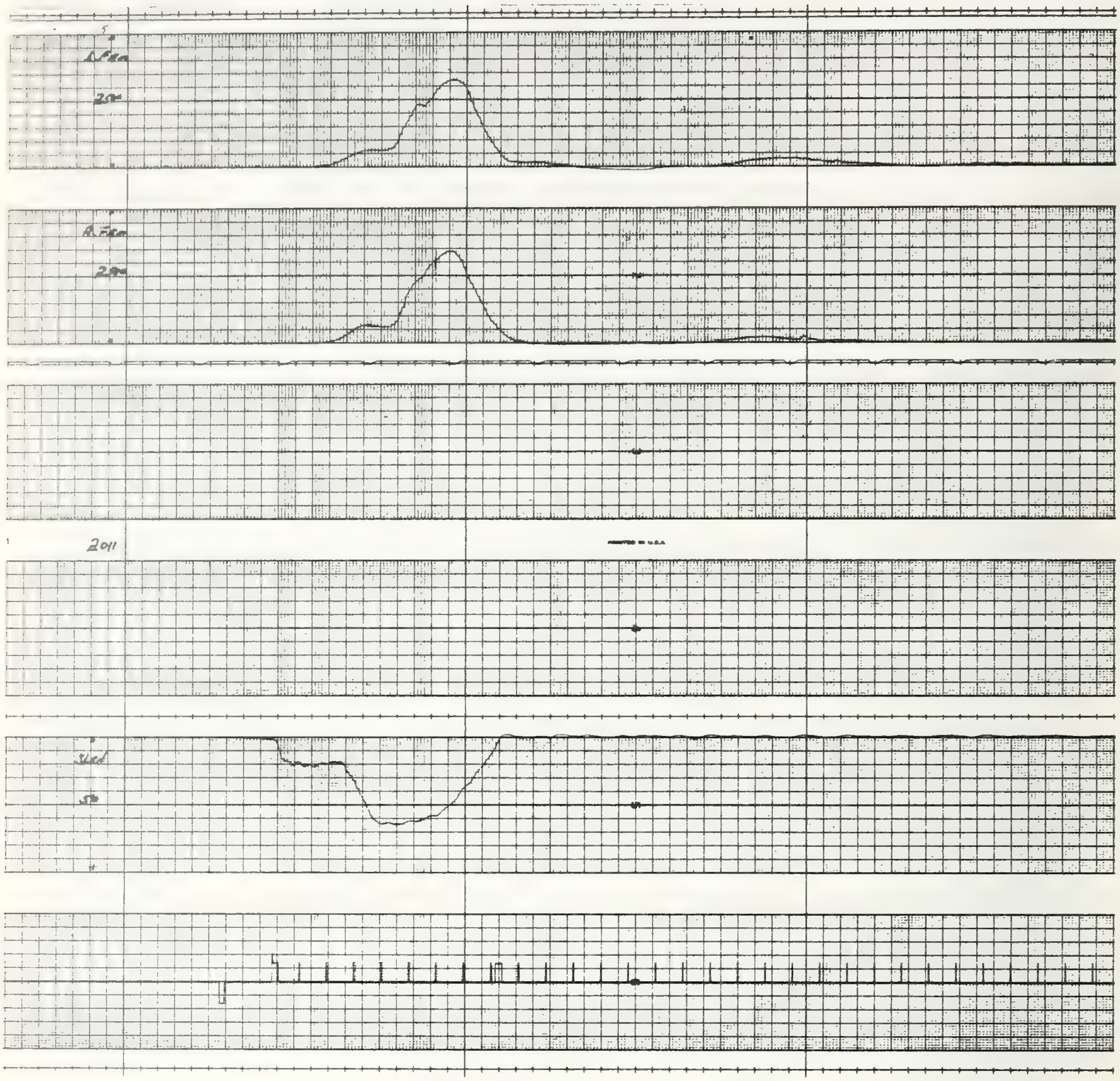
POST TEST
RUN 2011



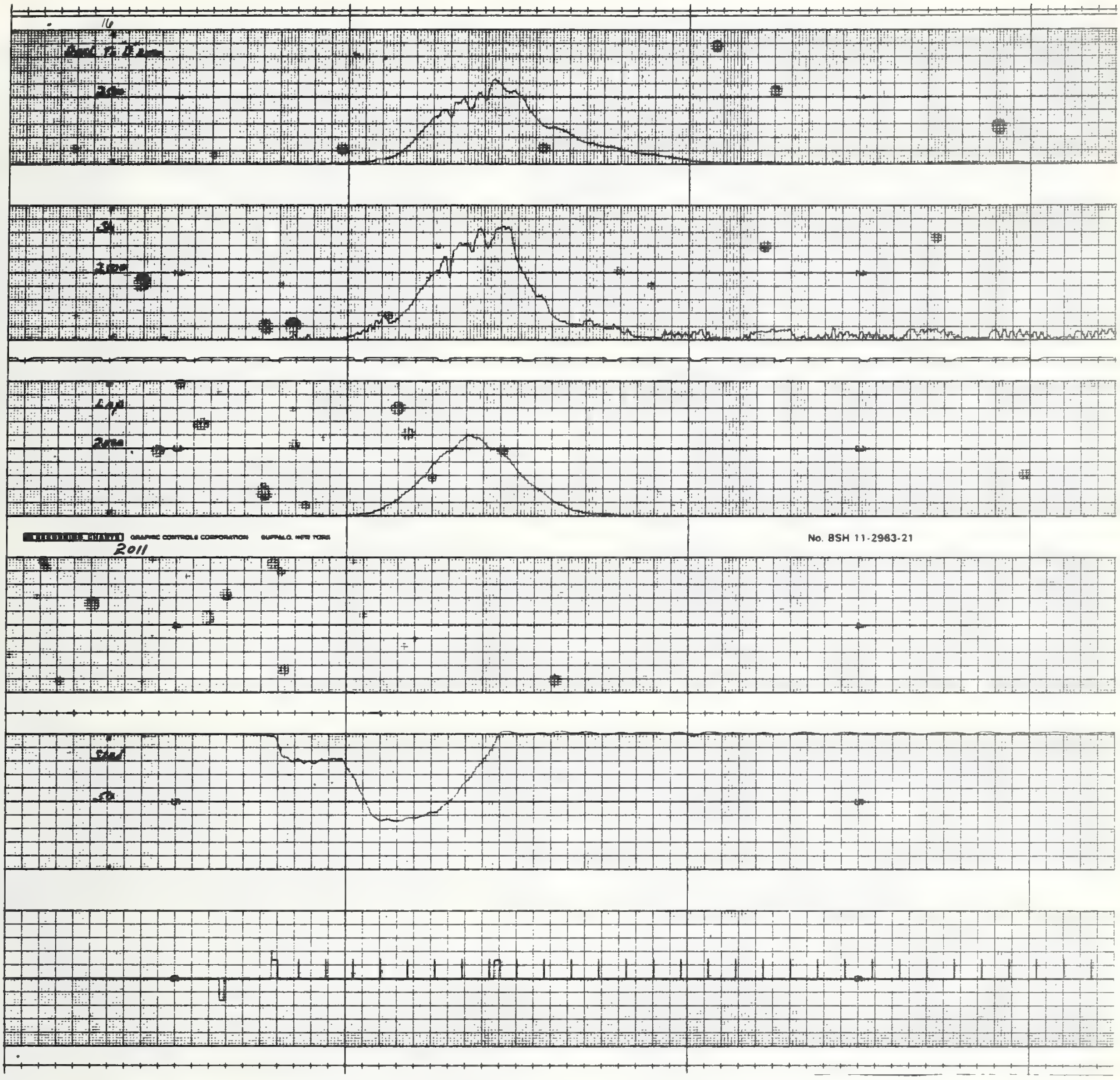
Time = 10 ms/division



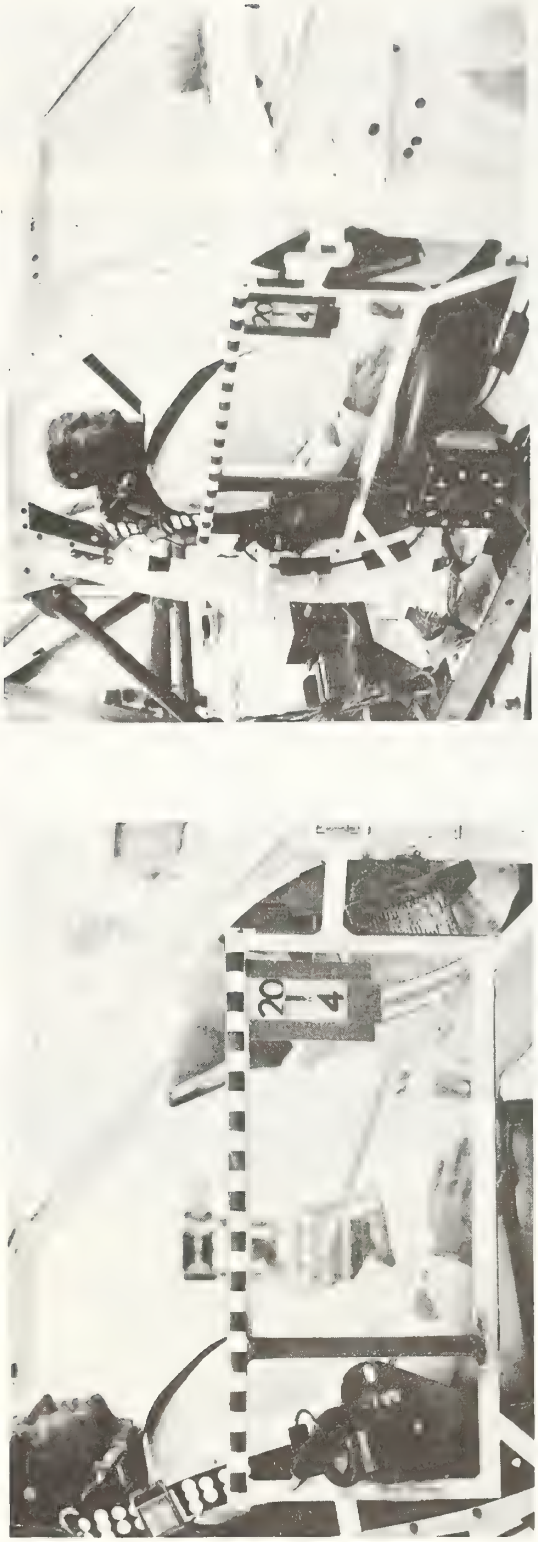
Time = 10 ms/division



Time = 10 ms/division



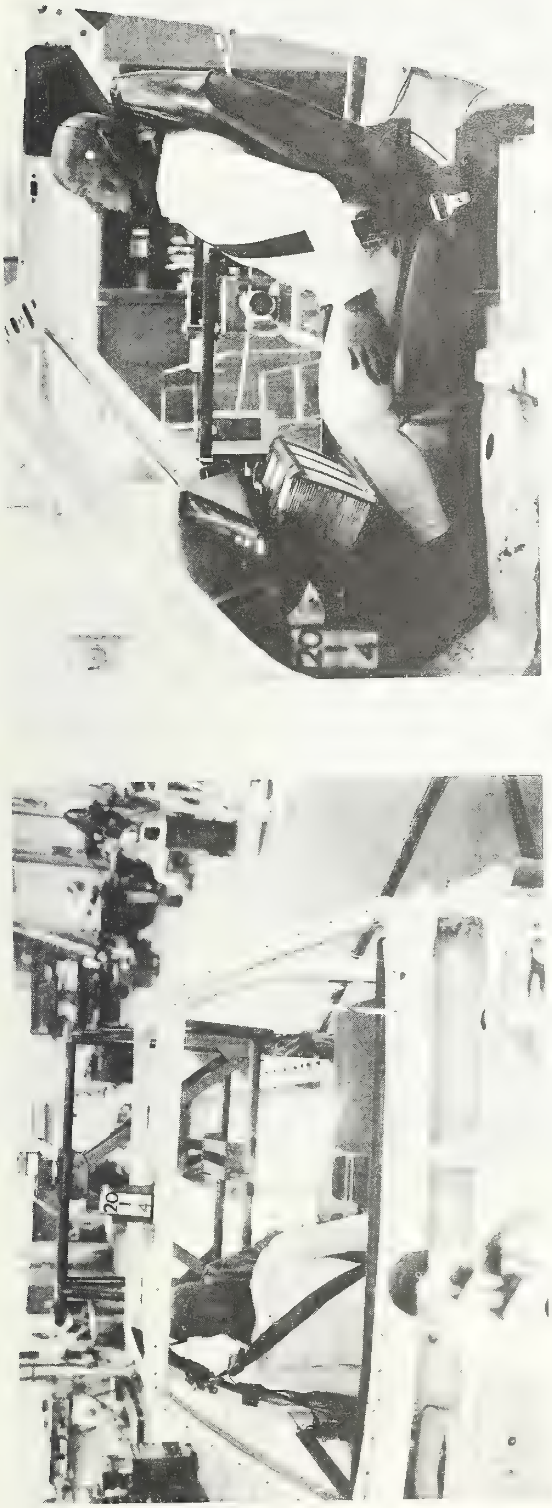
Time = 10 ms/division



PRETEST

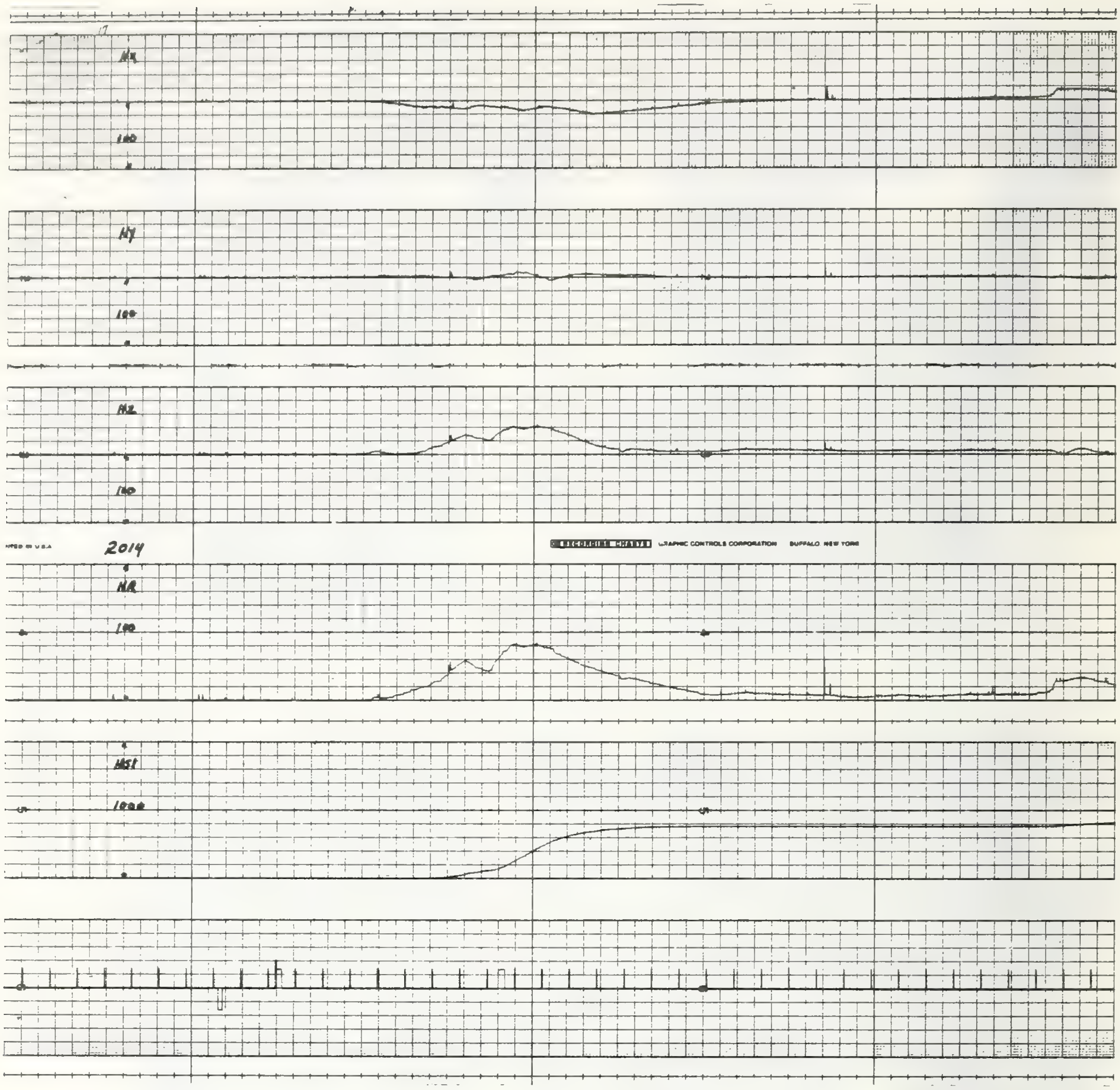
POST TEST

RUN 2014

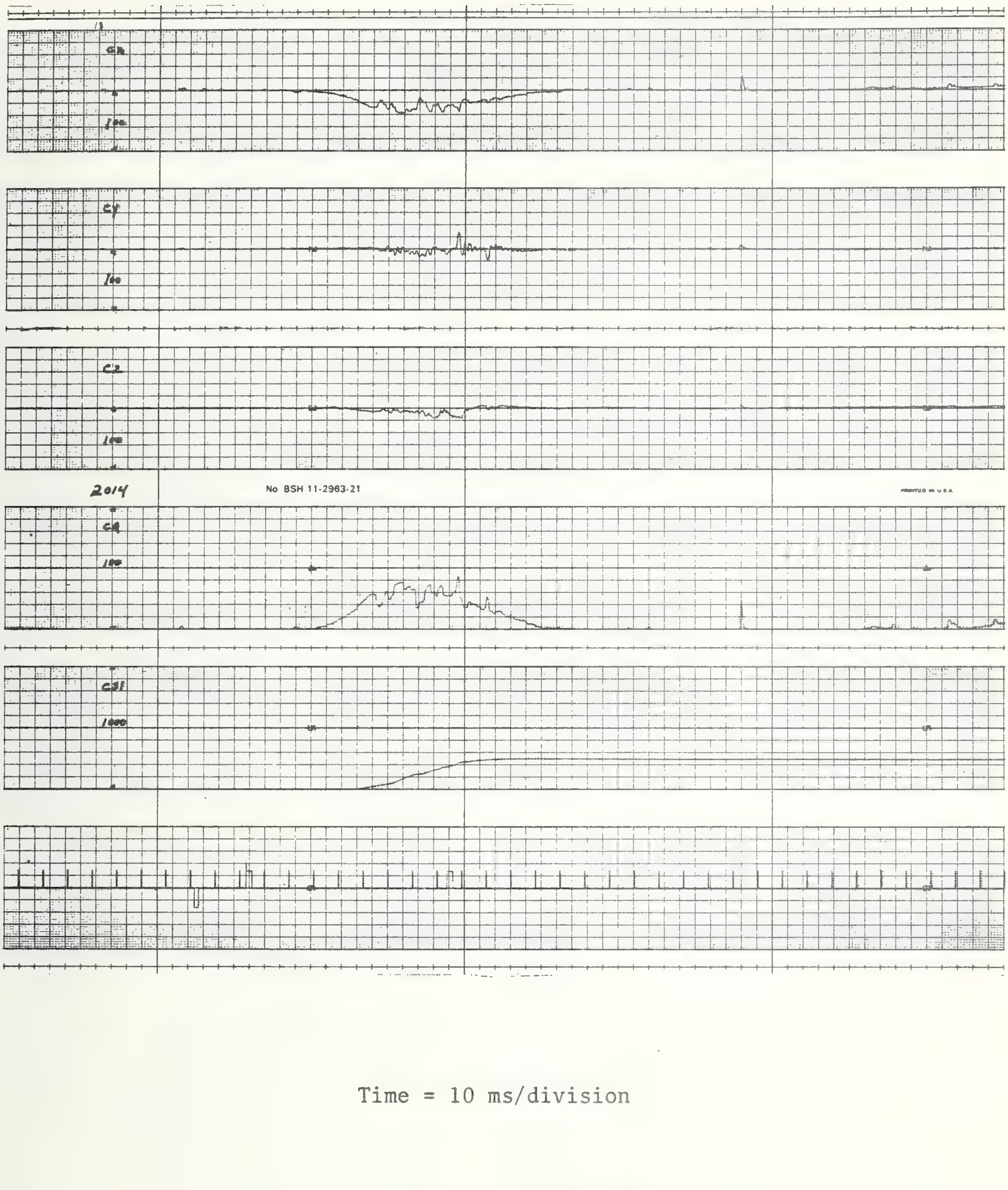


PRETEST

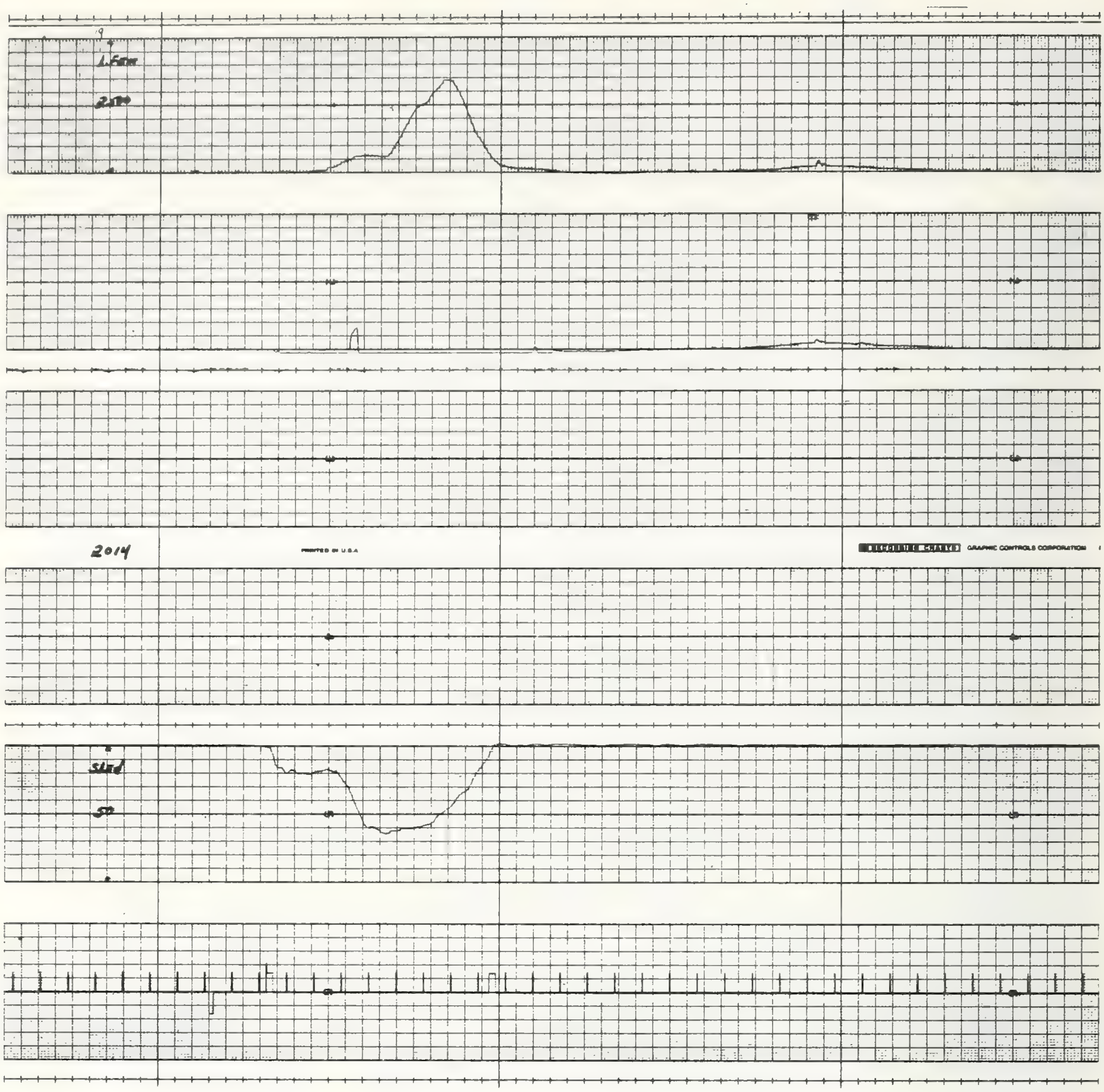
POST TEST
RUN 2014



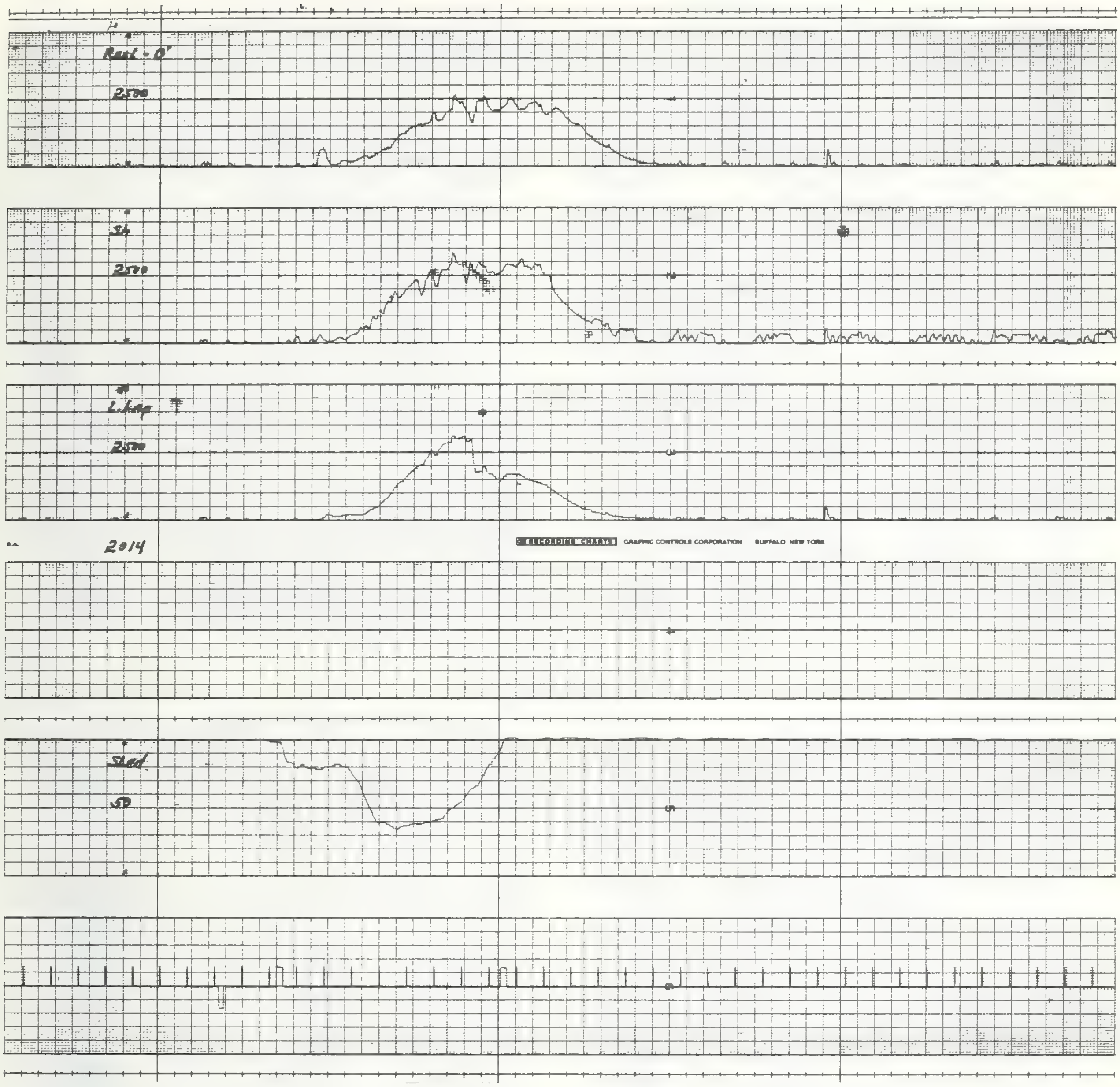
Time = 10 ms/division



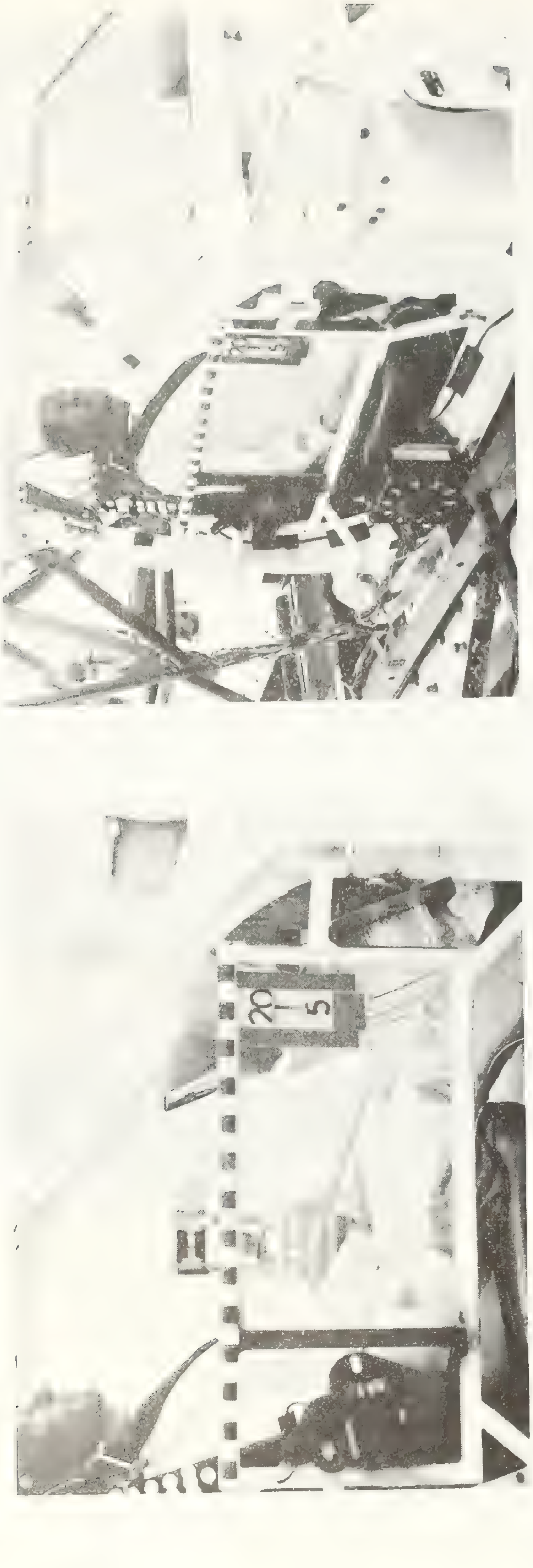
Time = 10 ms/division



Time = 10 ms/division

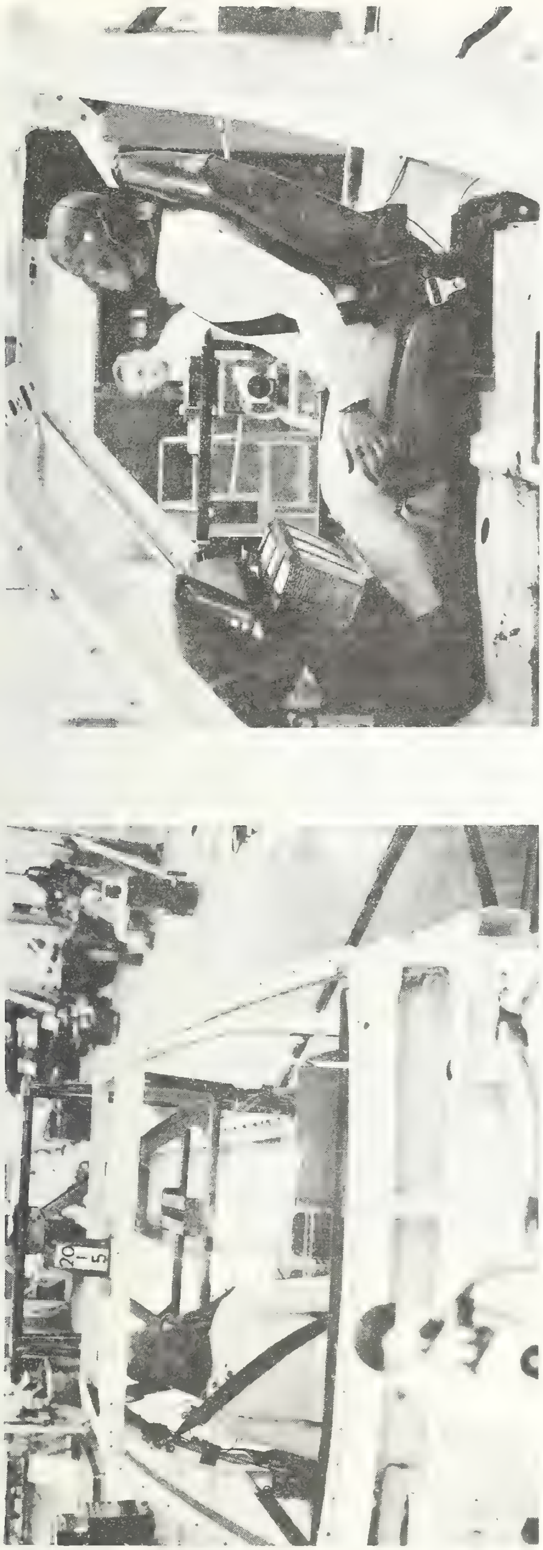


Time = 10 ms/division



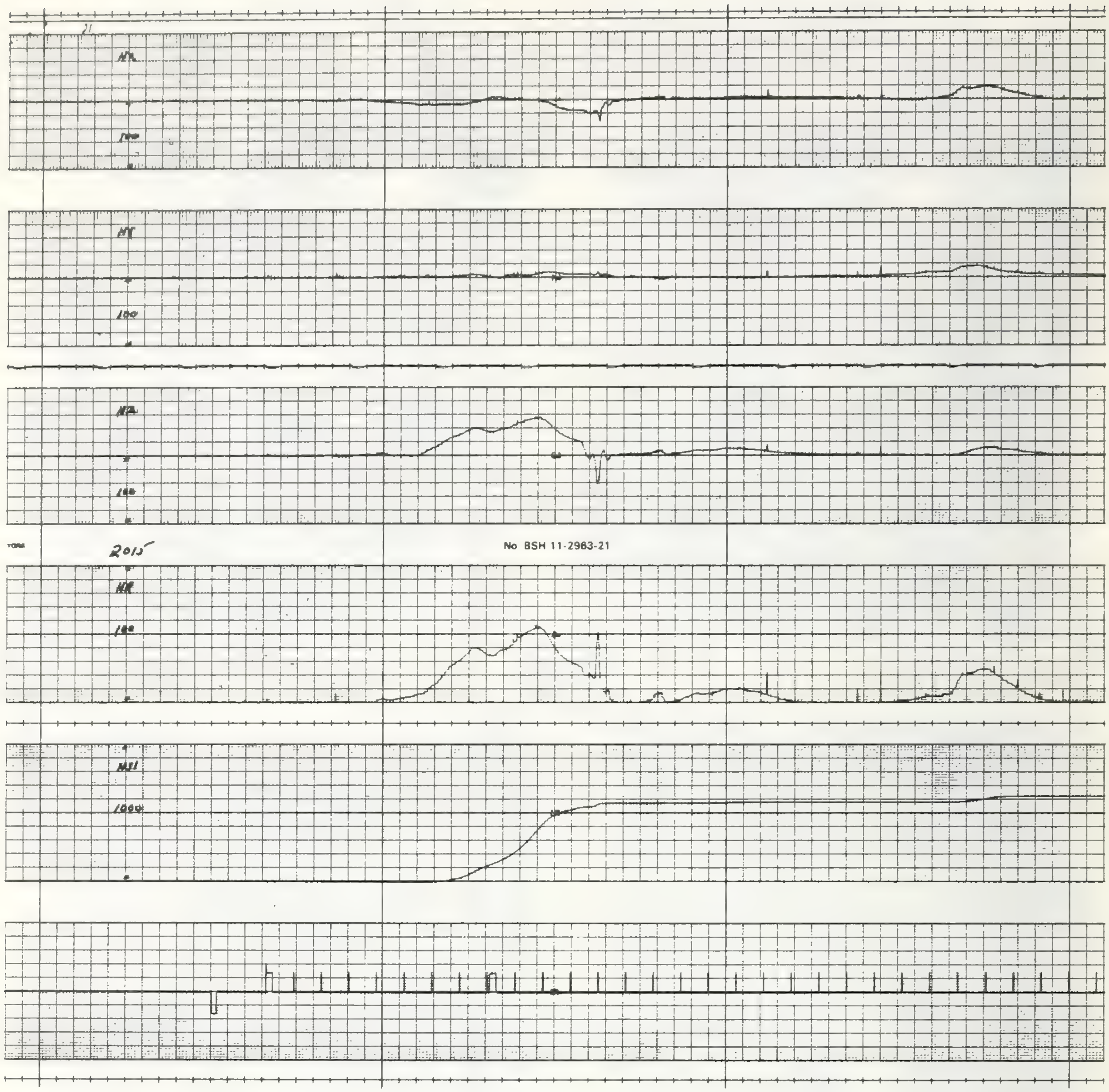
PRETEST

POST TEST
RUN 2015

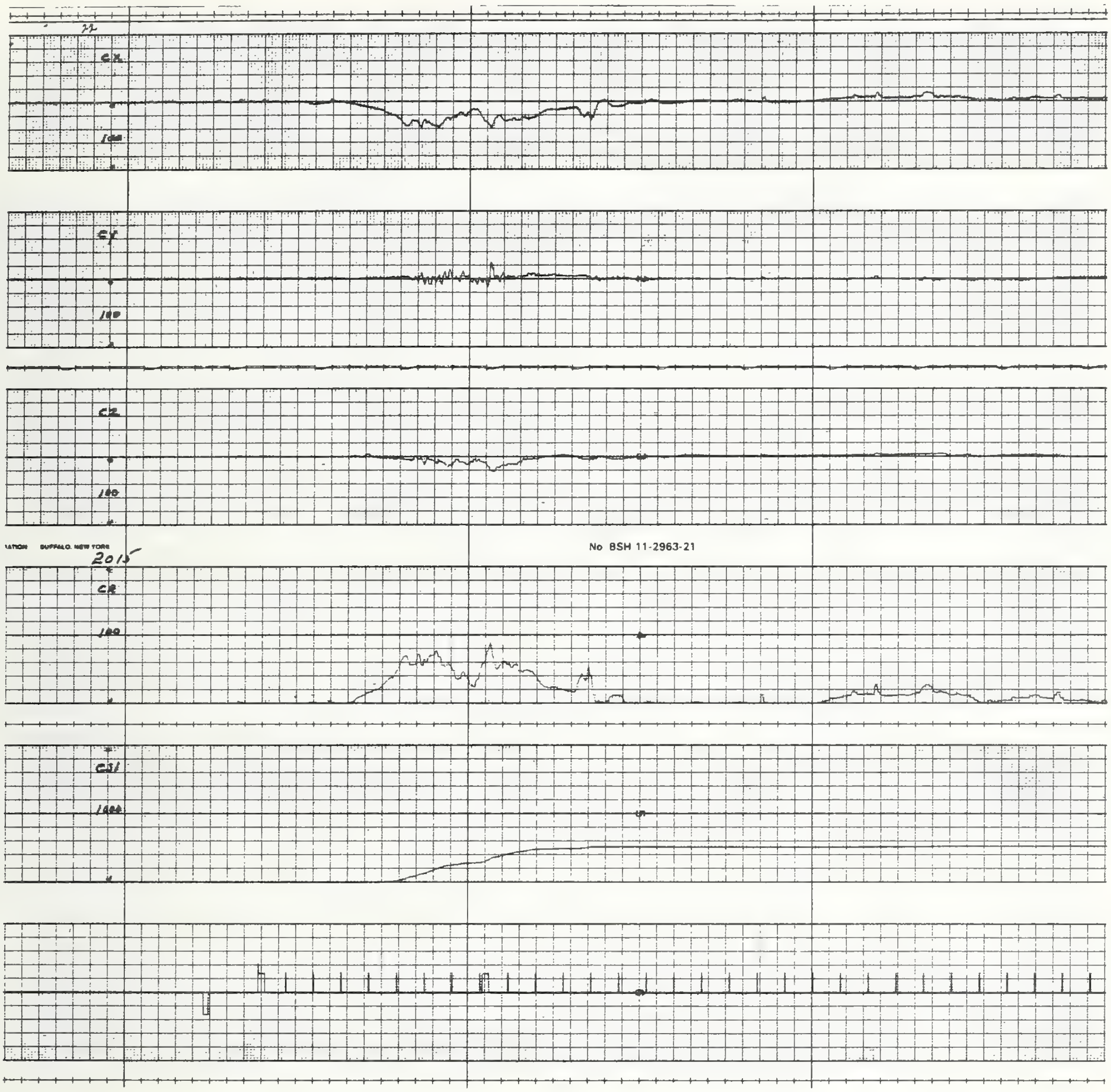


PRETEST

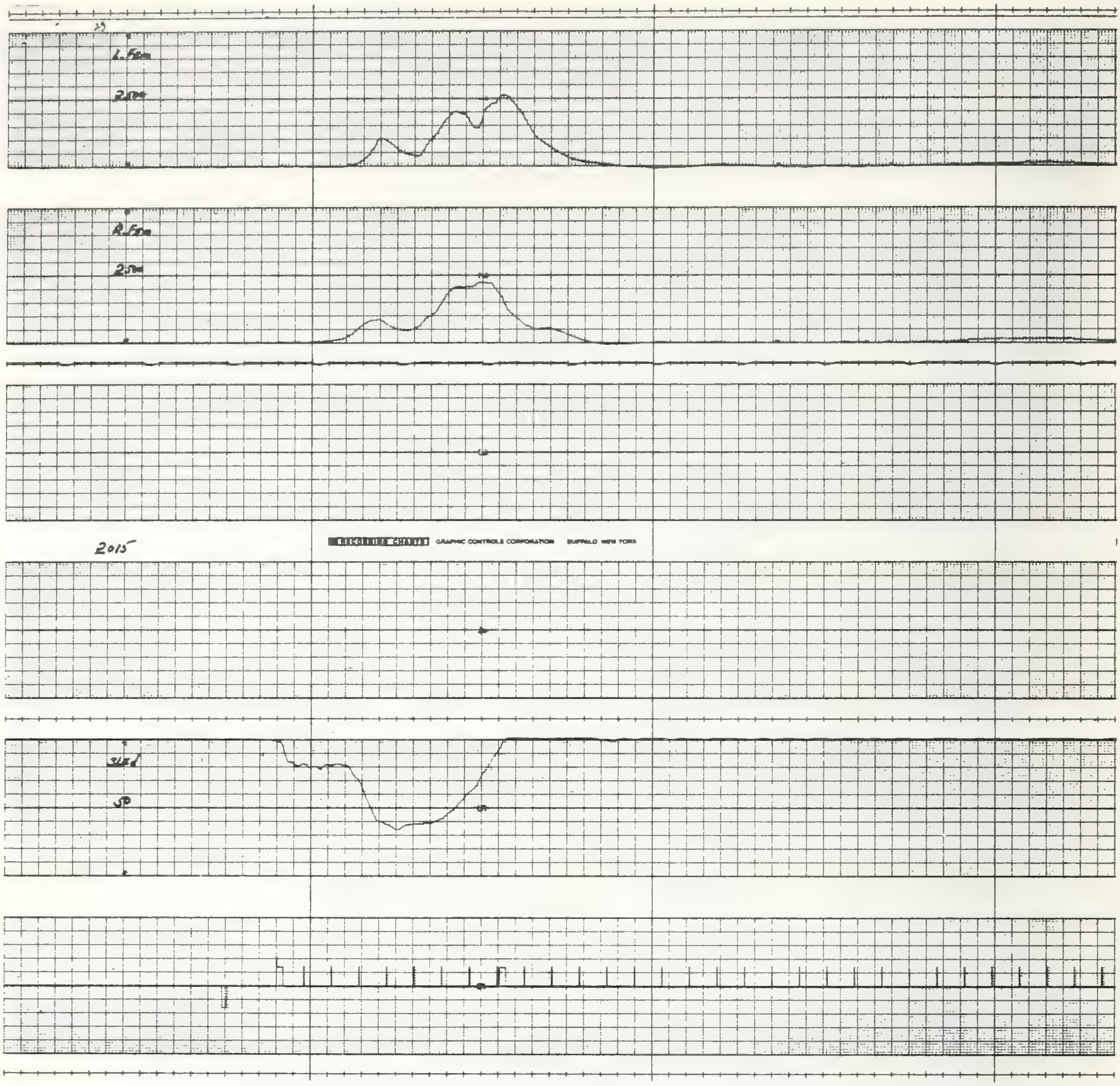
POST TEST
RUN 2015



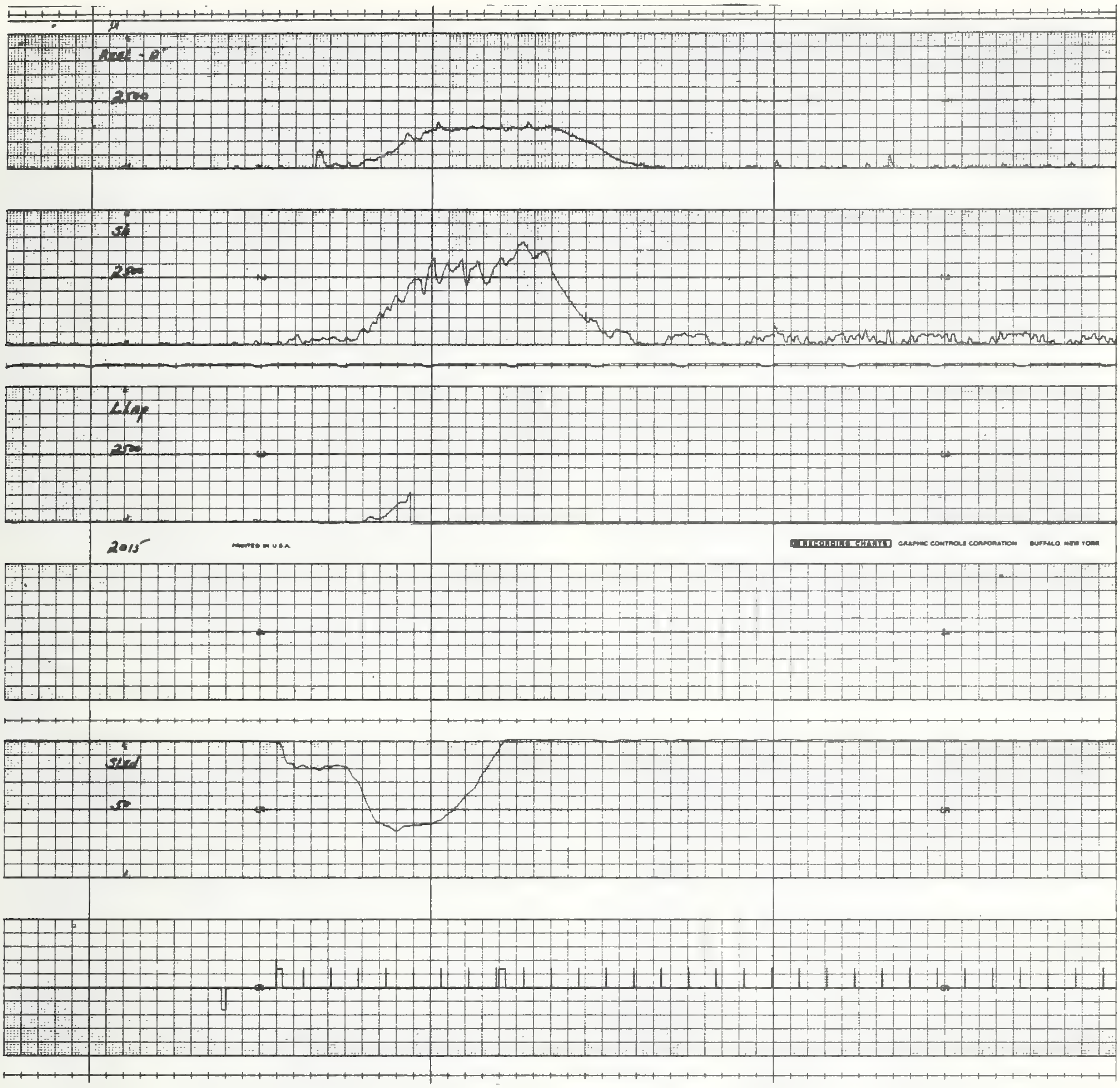
Time = 10 ms/division



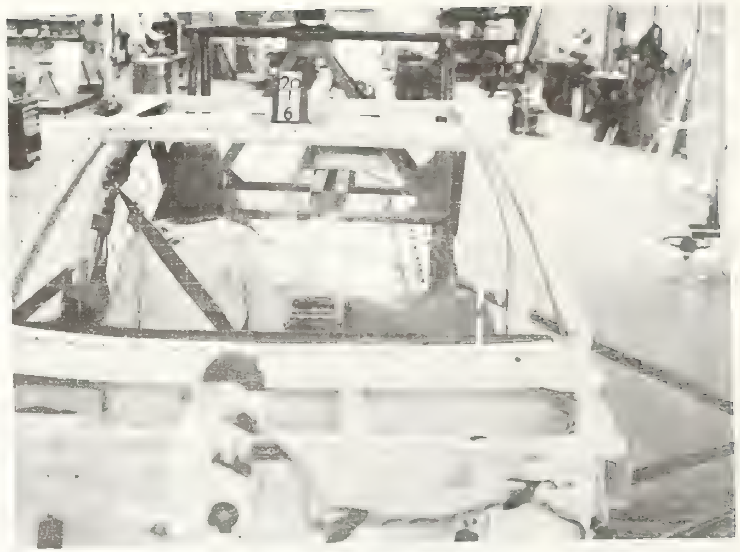
Time = 10 ms/division



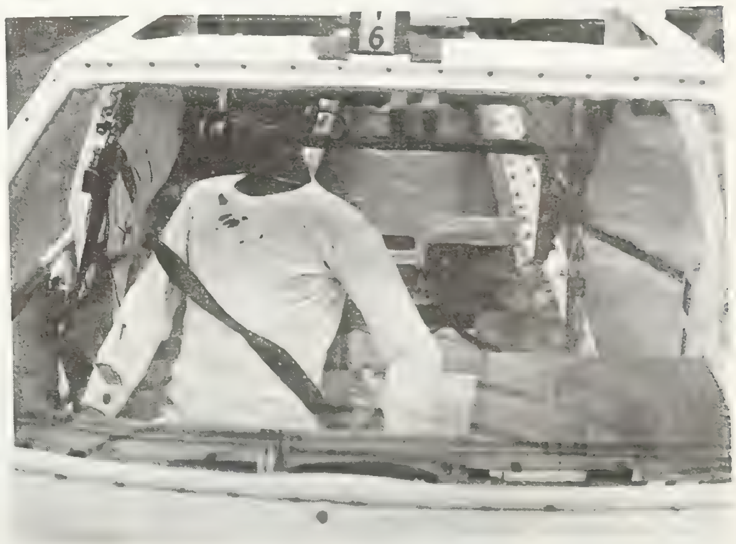
Time = 10 ms/division



Time = 10 ms/division



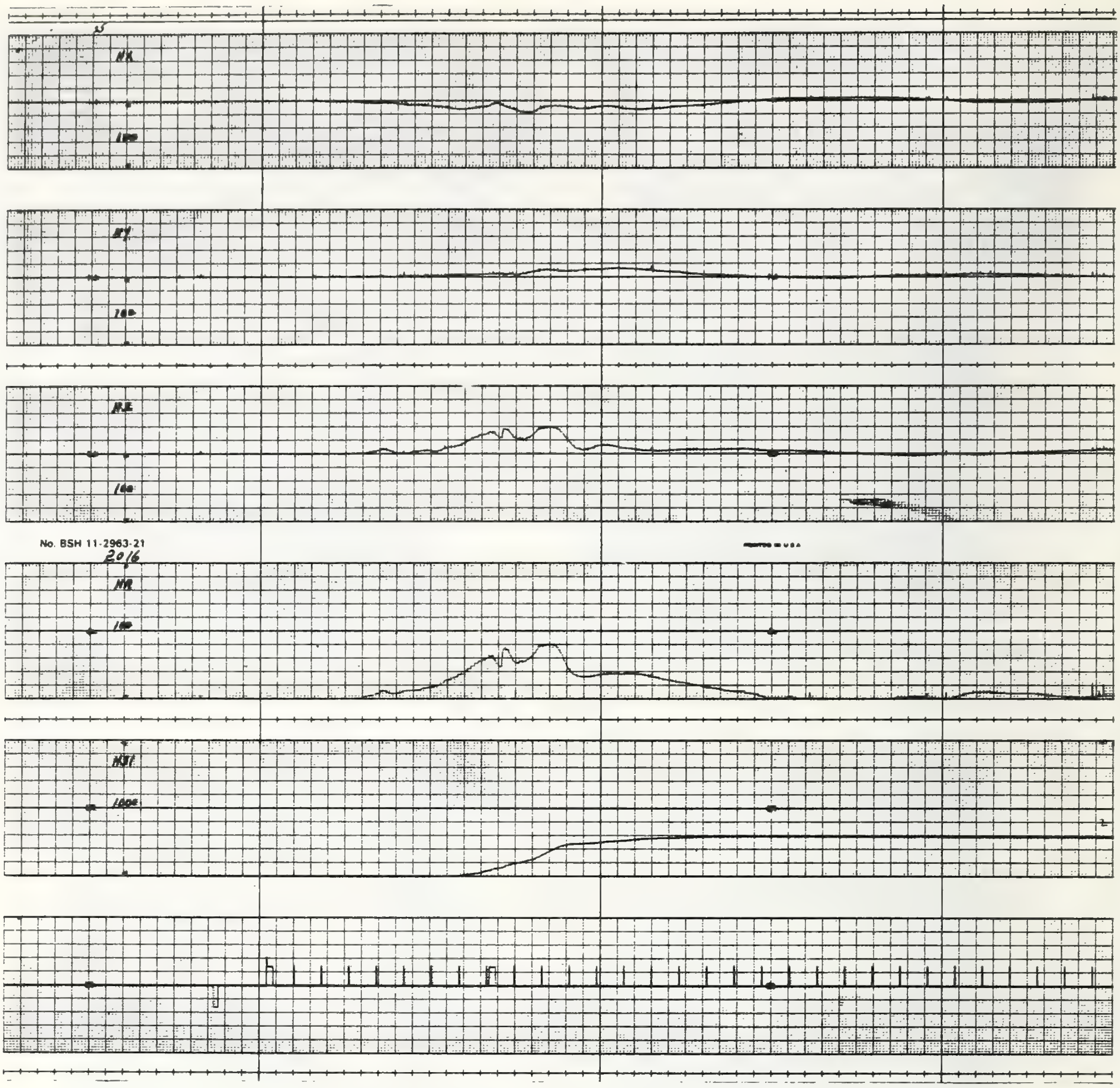
PRETEST



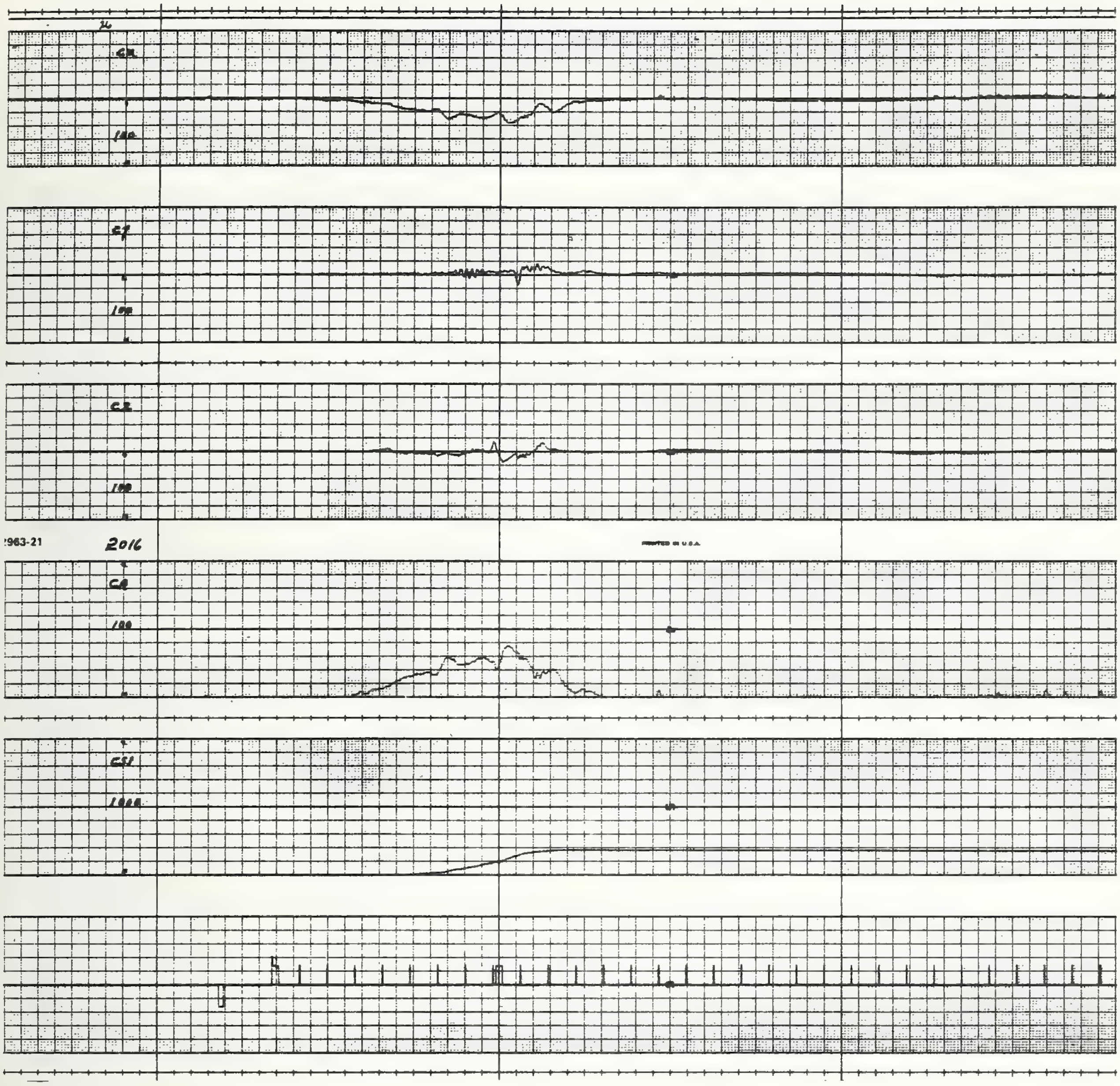
POST TEST
RUN-2016

PRETEST

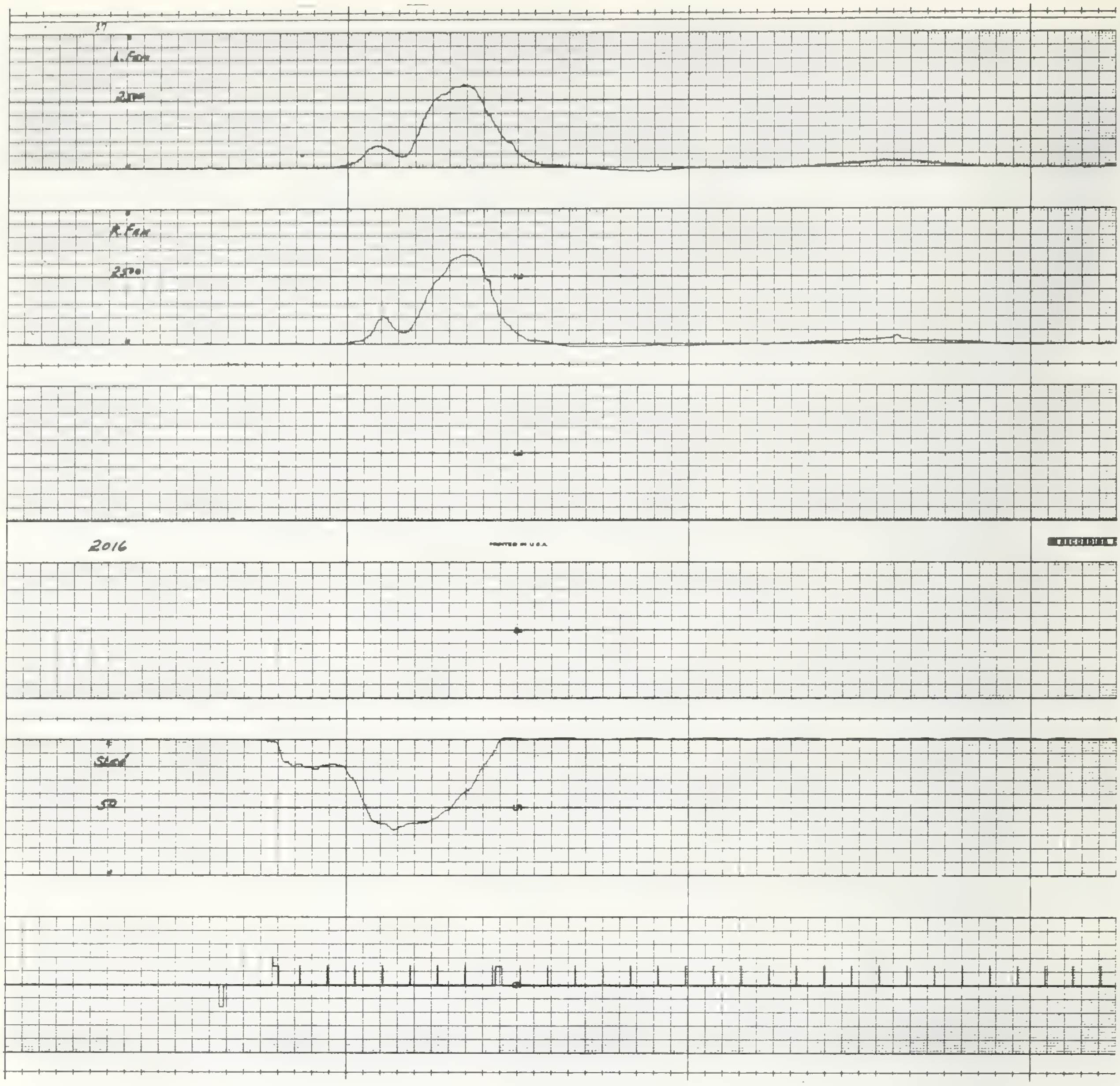
POST TEST
RUN 2016



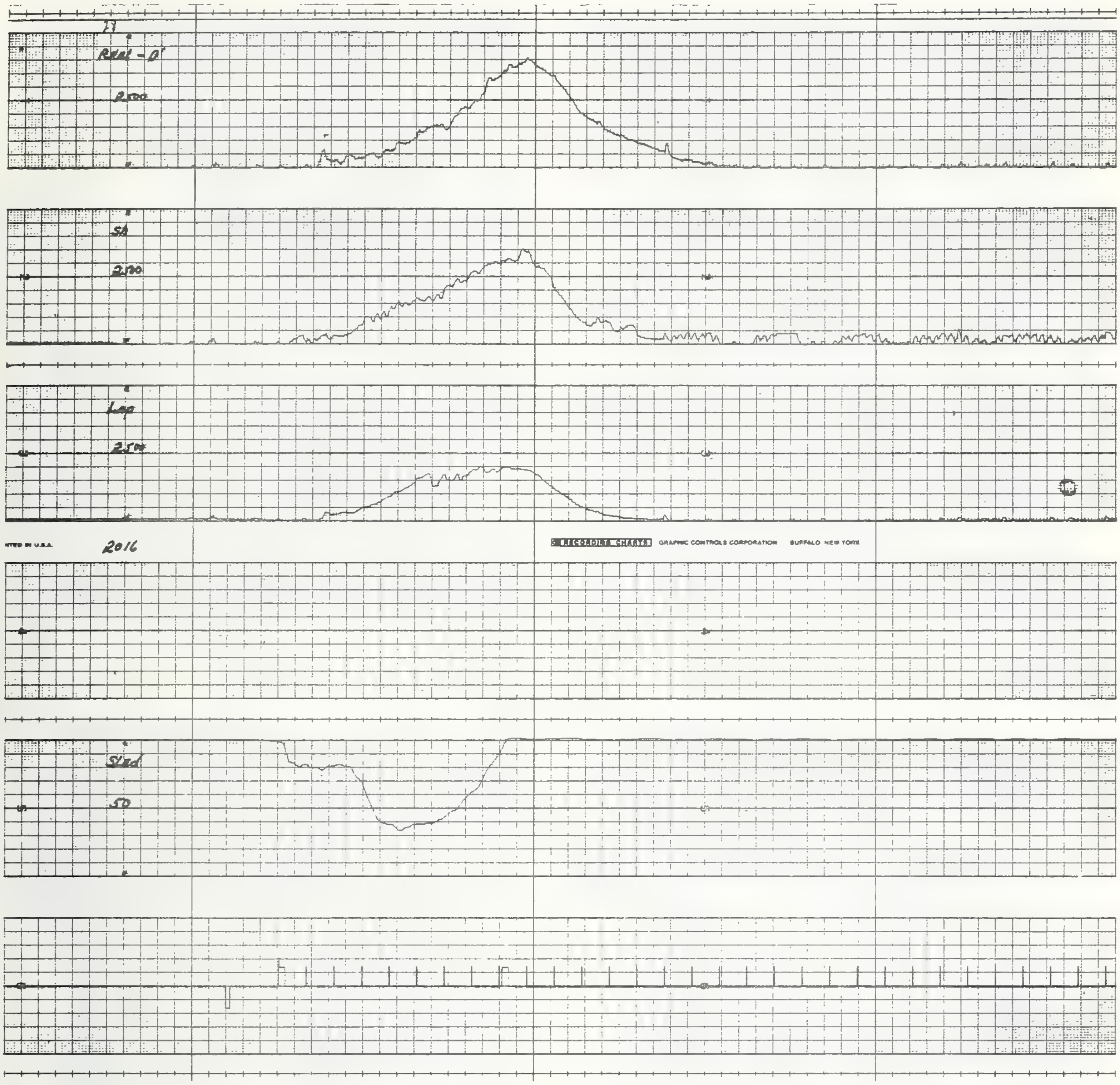
Time = 10 ms/division



Time = 10 ms/division



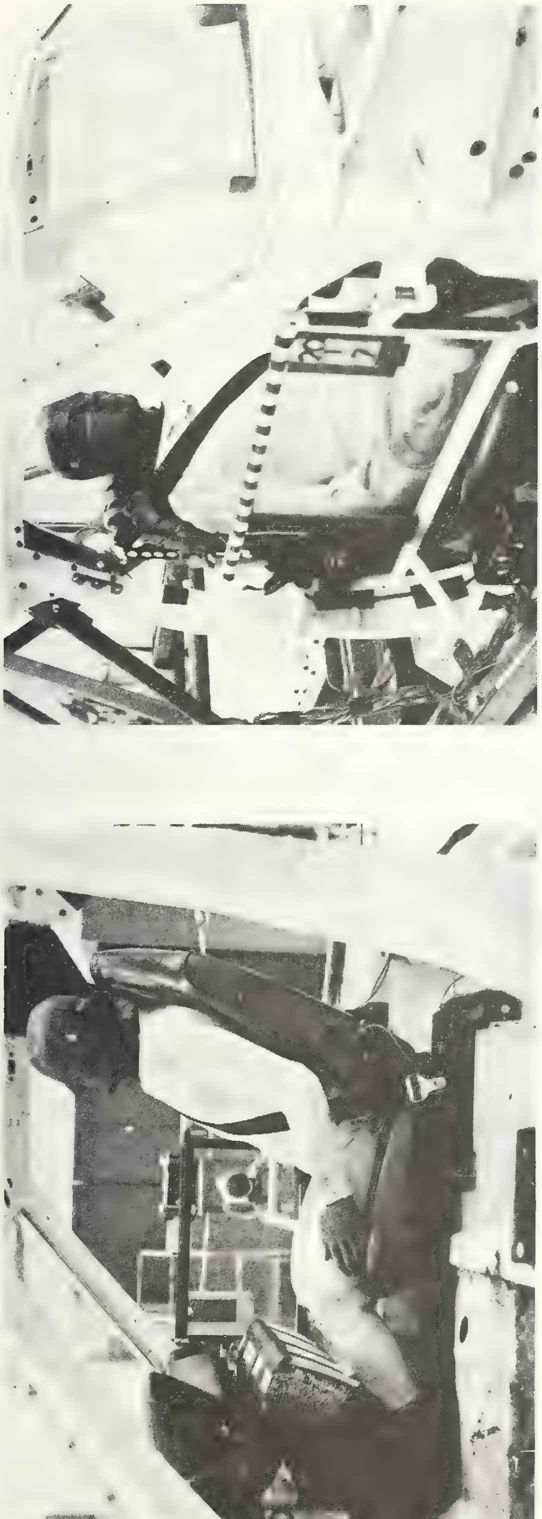
Time = 10 ms/division



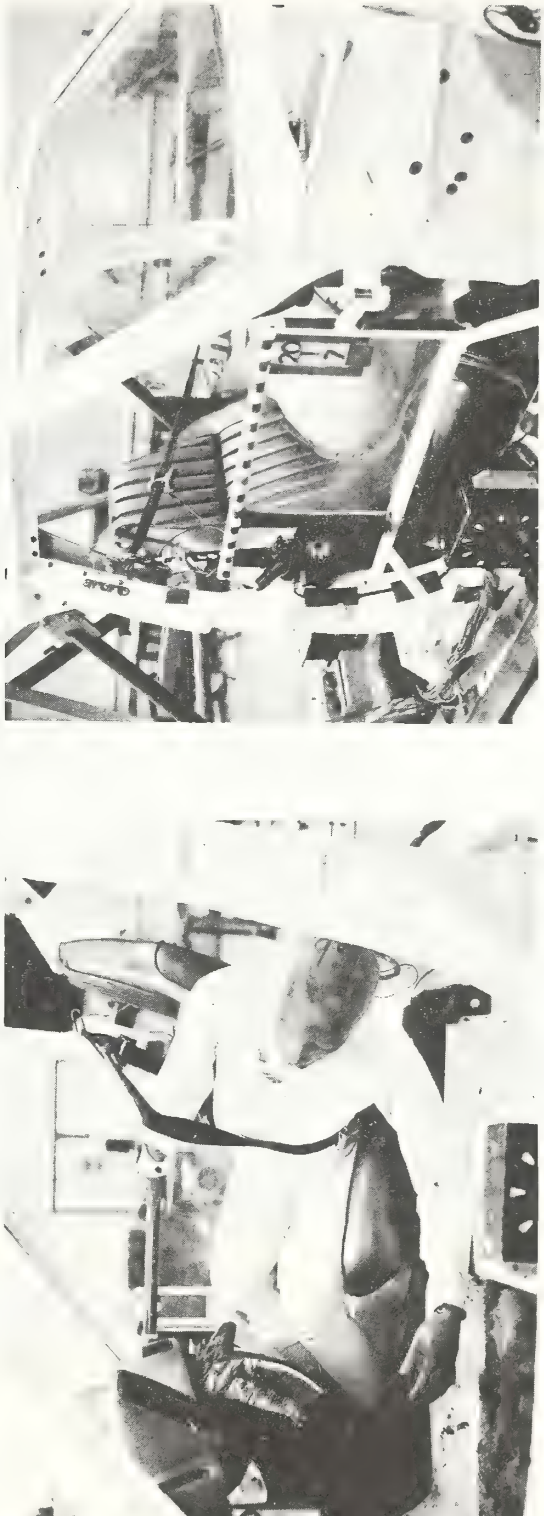
Time = 10 ms/division

PRETEST

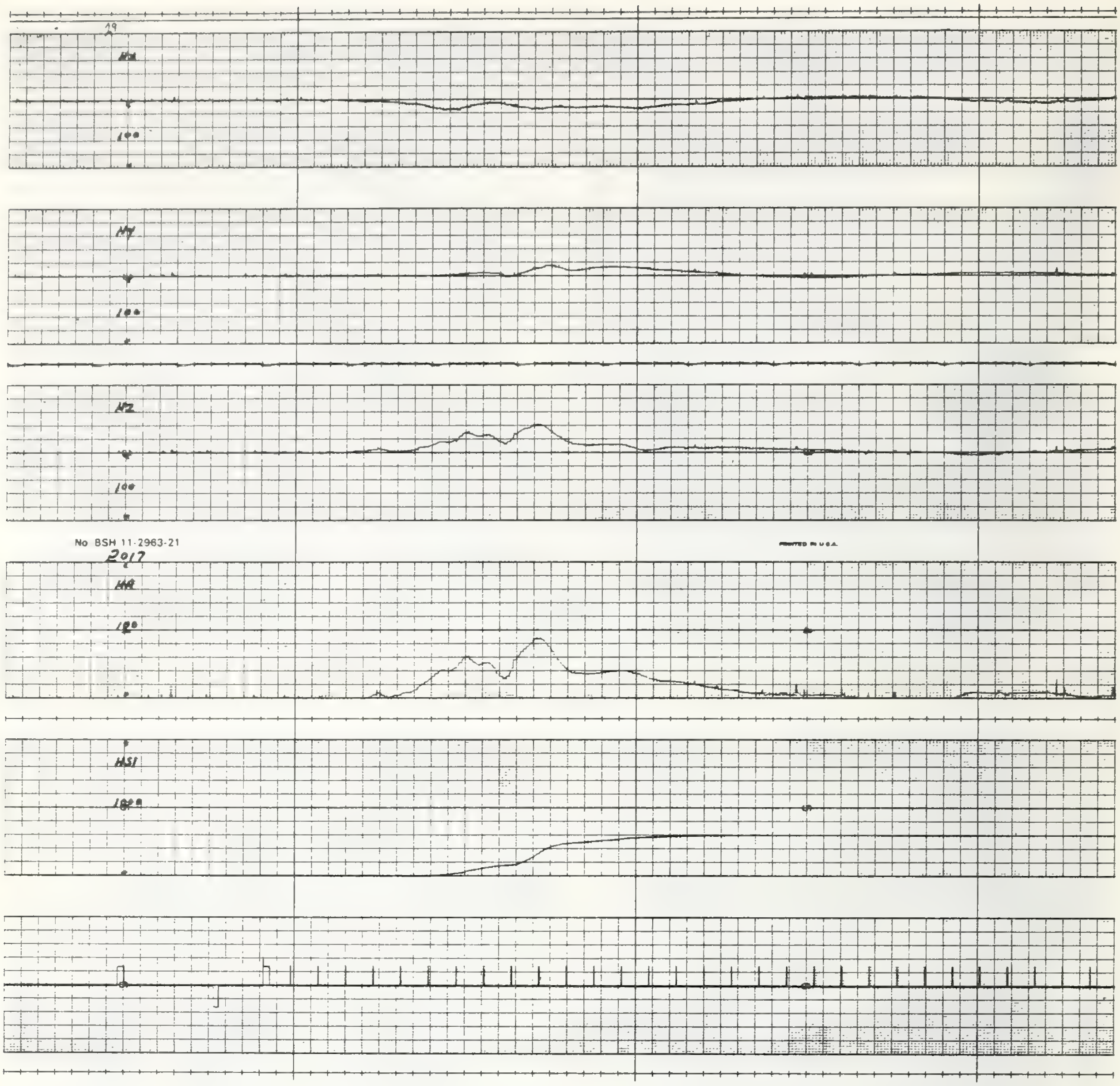
POST TEST
RUN 2017



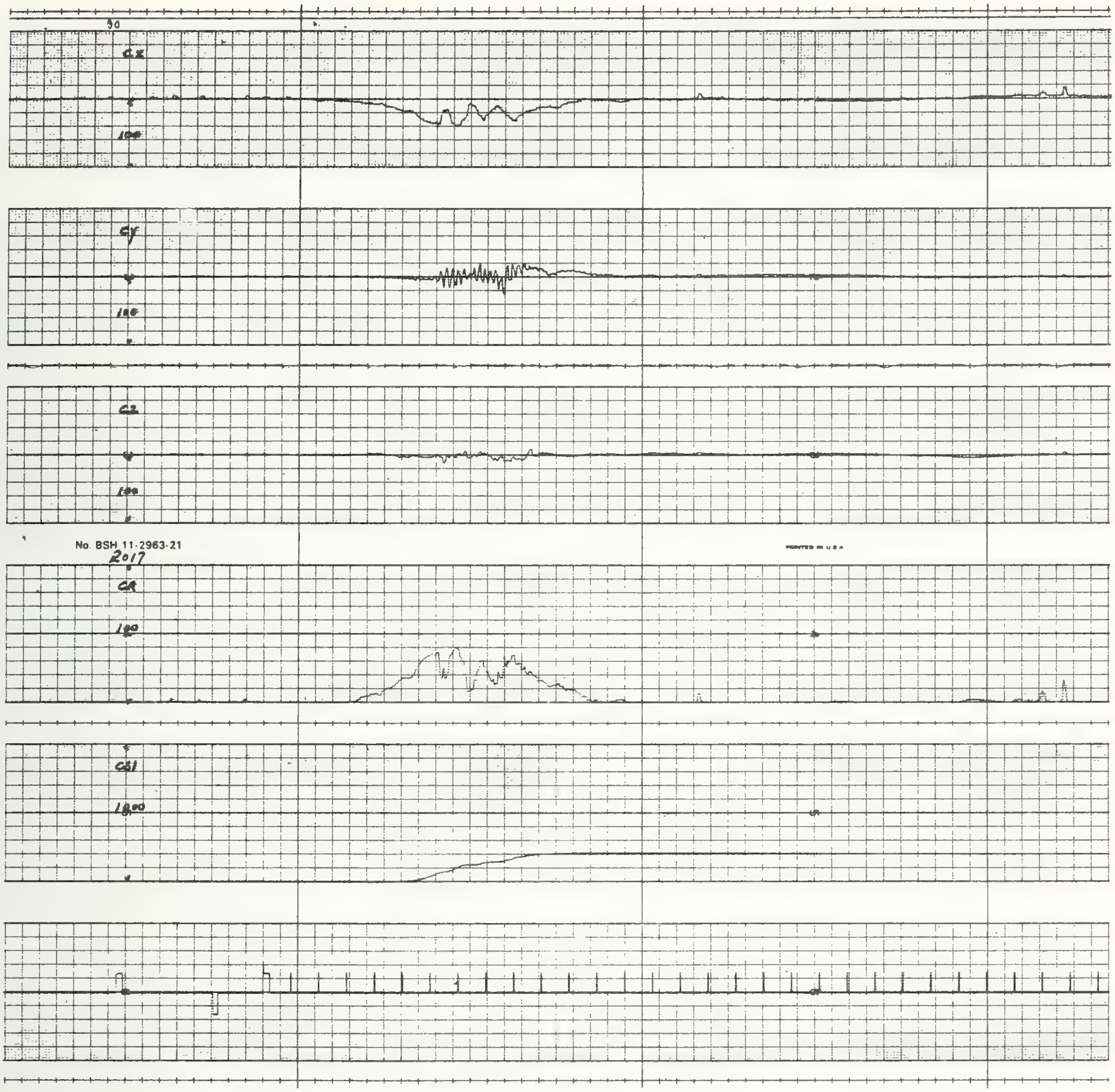
PRETEST



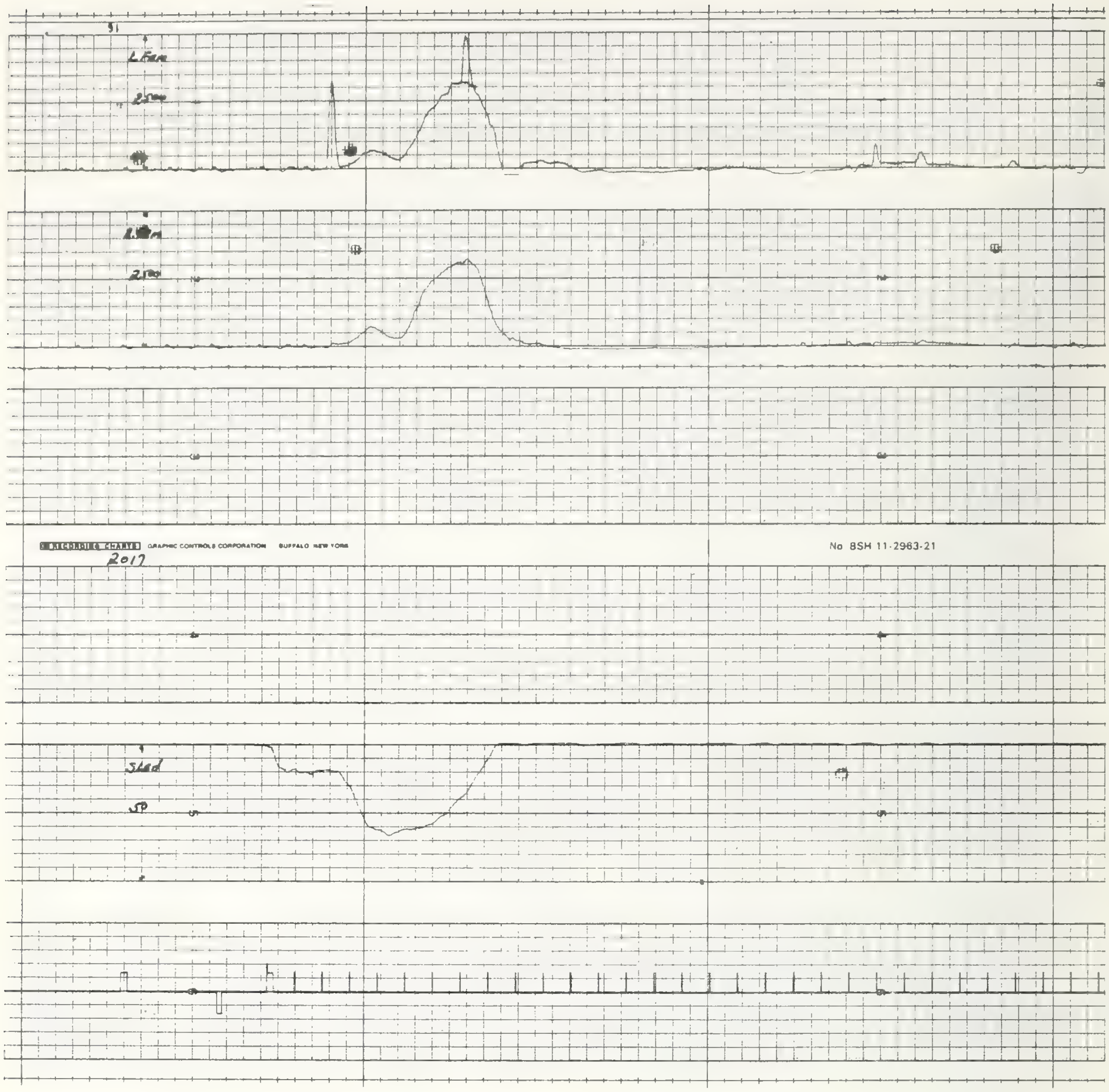
POST TEST
RUN 2017



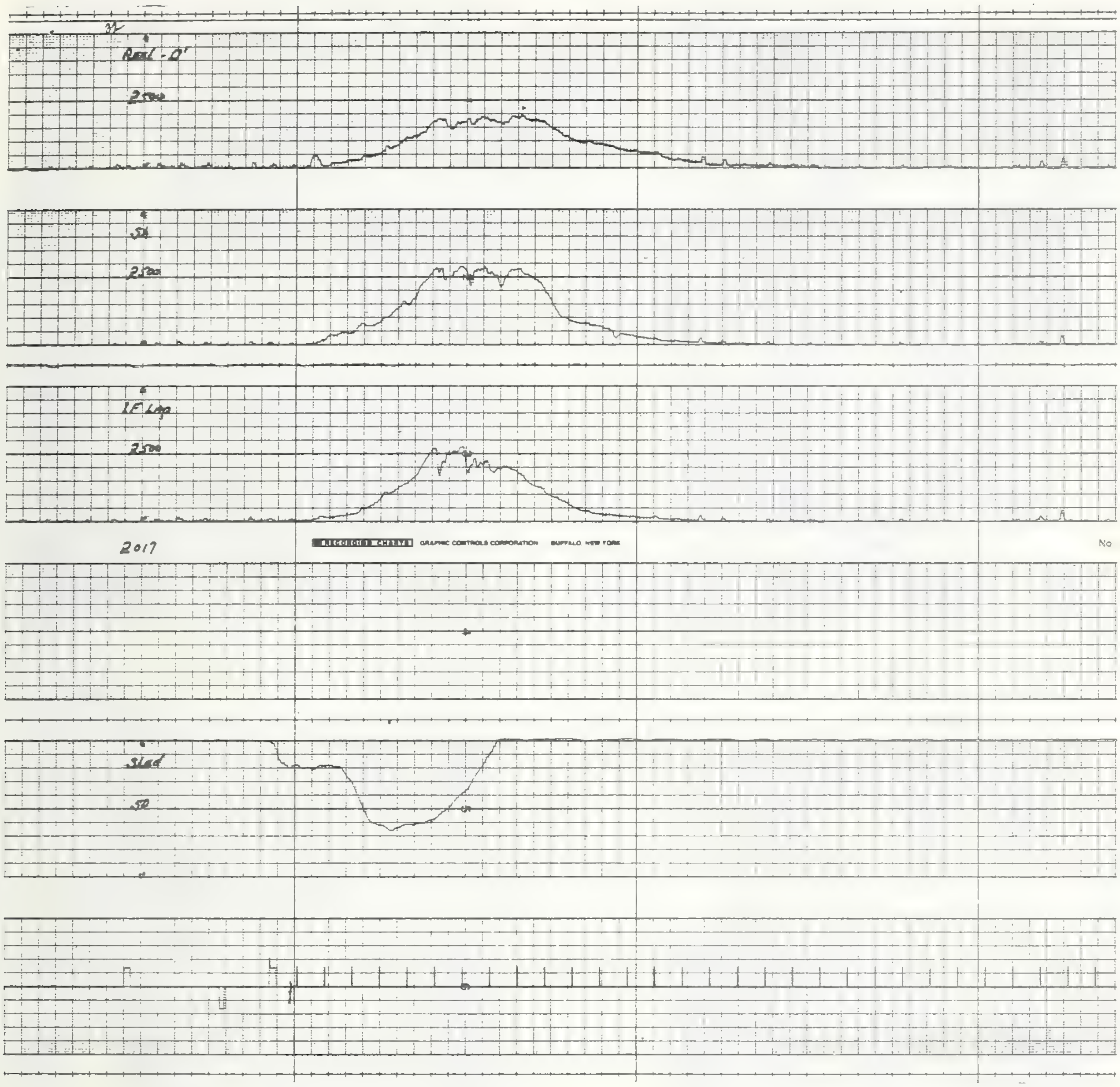
Time = 10 ms/division



Time = 10 ms/division



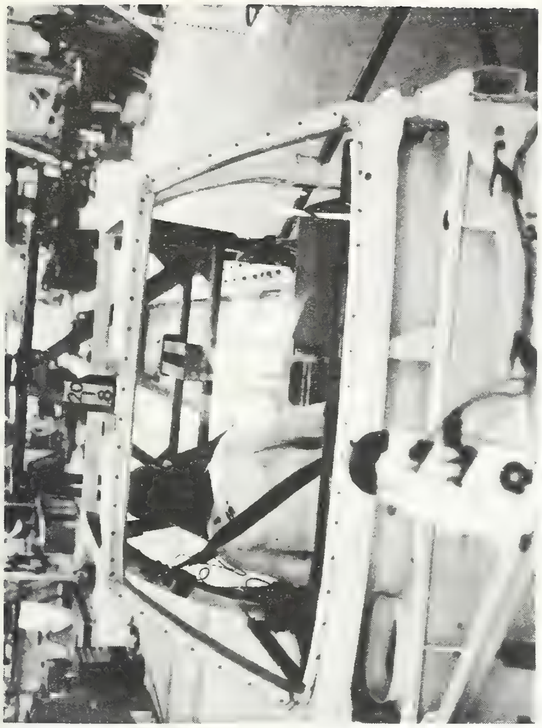
Time = 10 ms/division

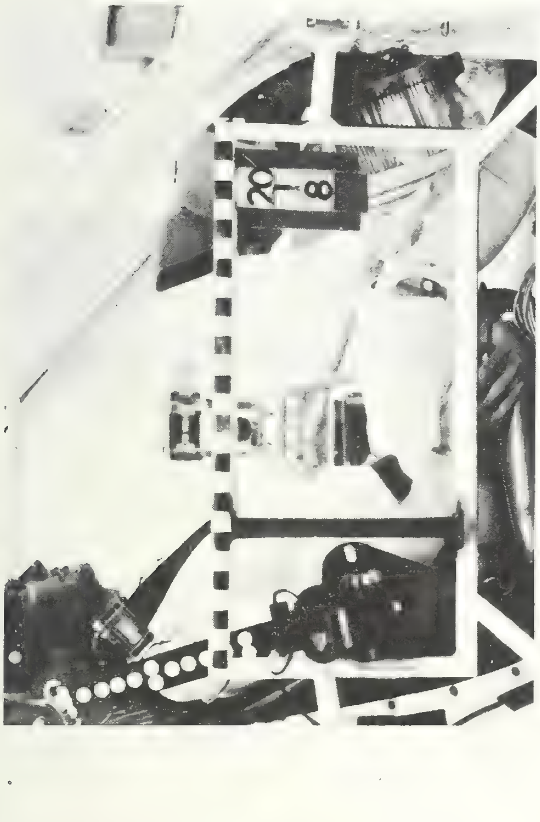


Time = 10 ms/division

PRETEST

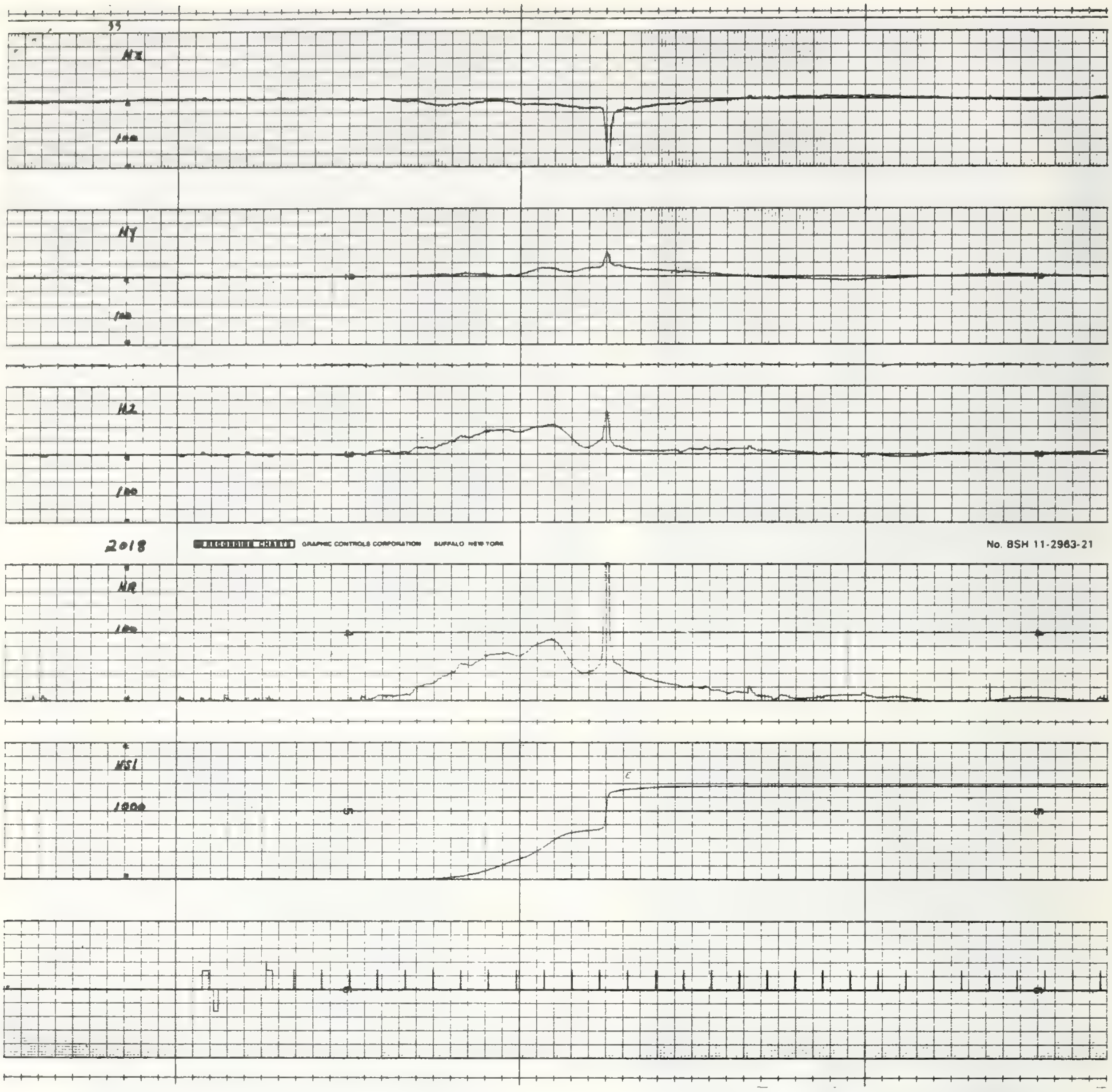
POST TEST
RUN 2018



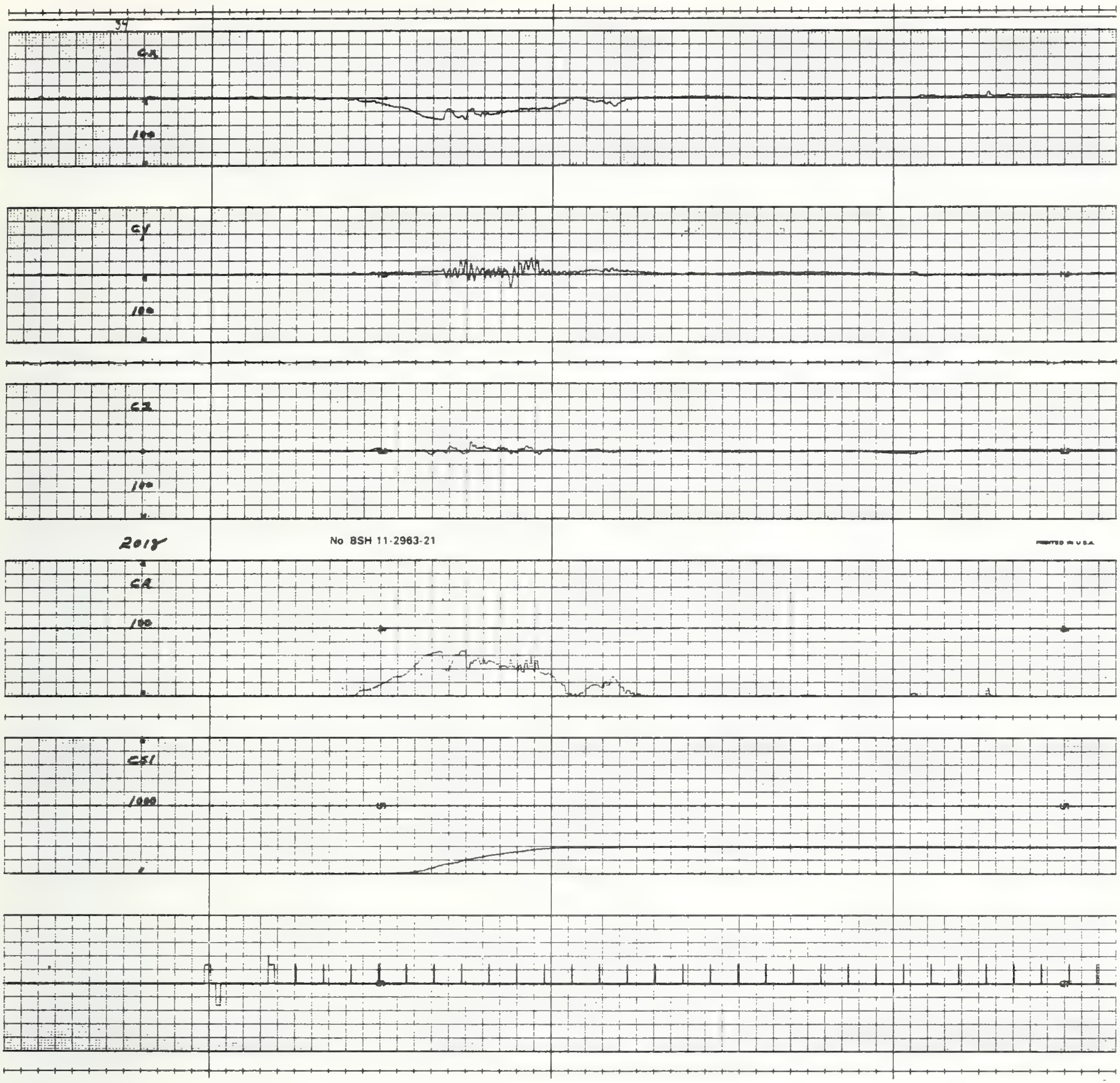


PRETEST

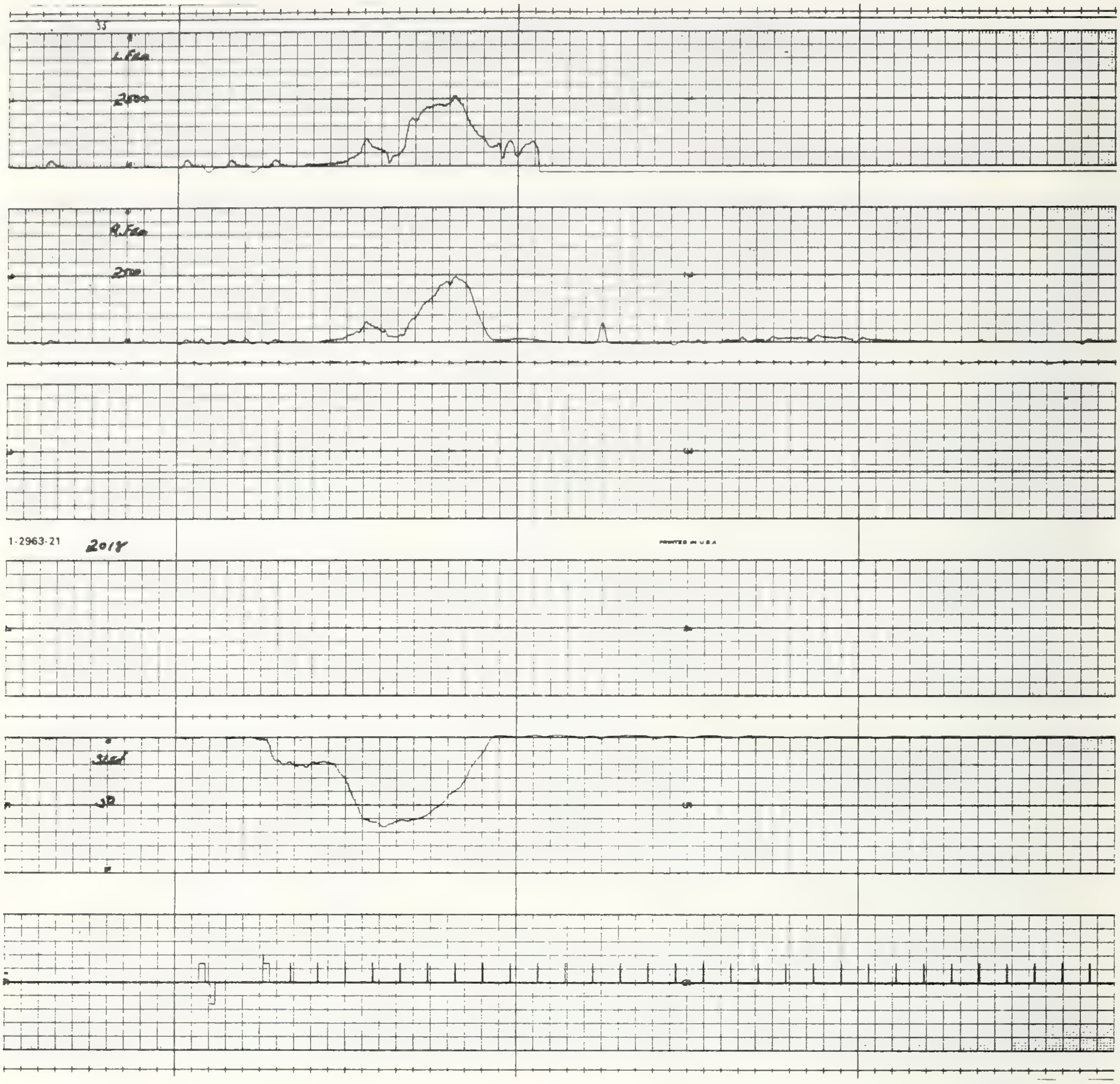
POST TEST
RUN 2018



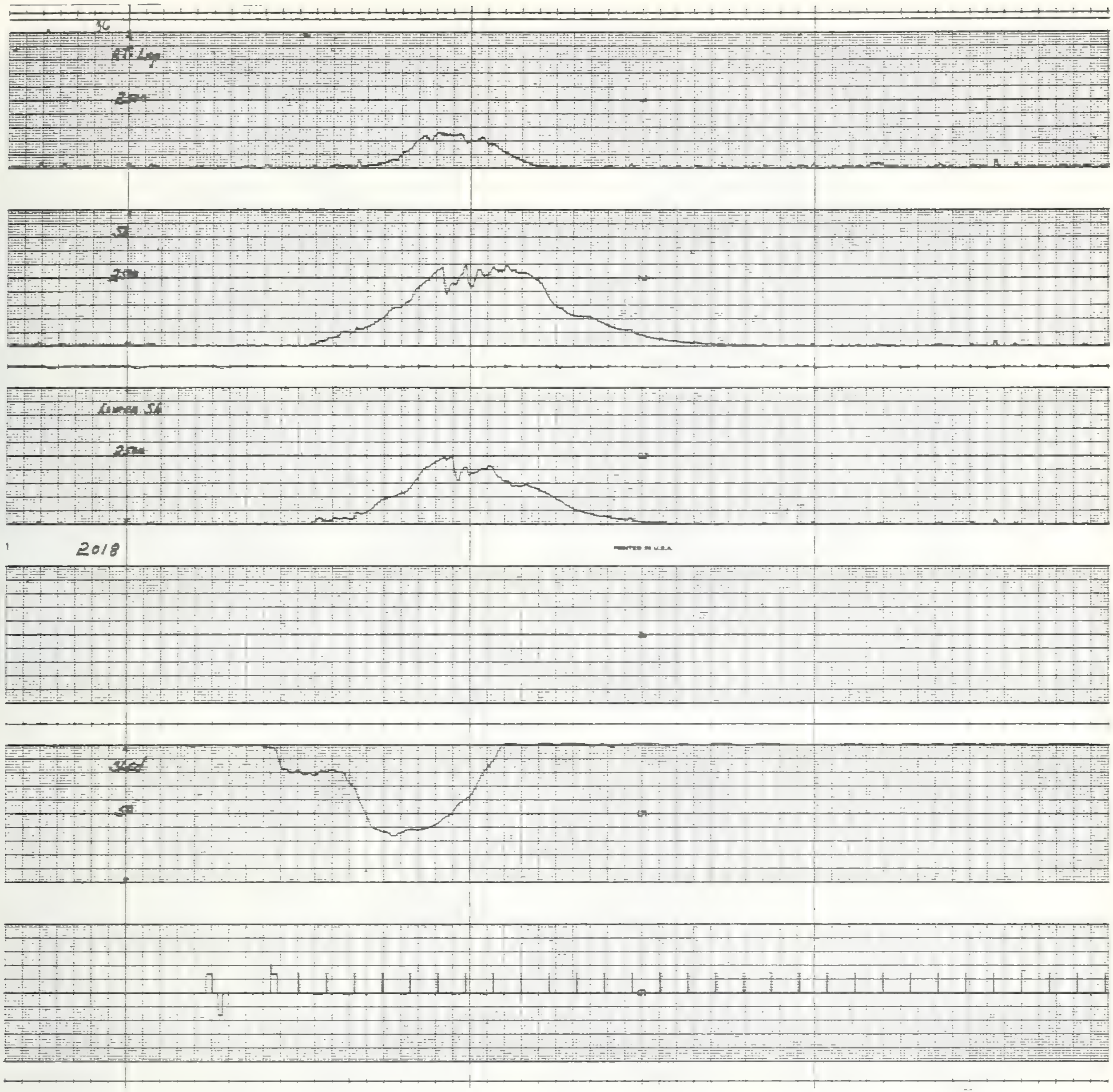
Time = 10 ms/division



Time = 10 ms/division

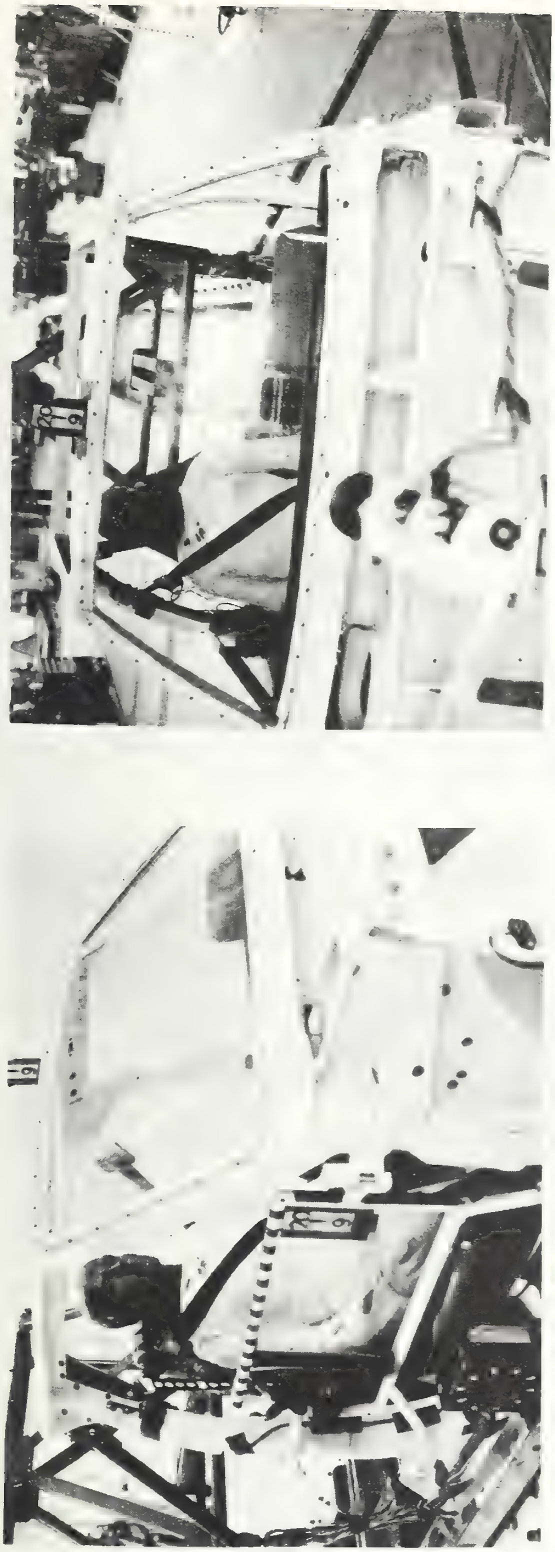


Time = 10 ms/division



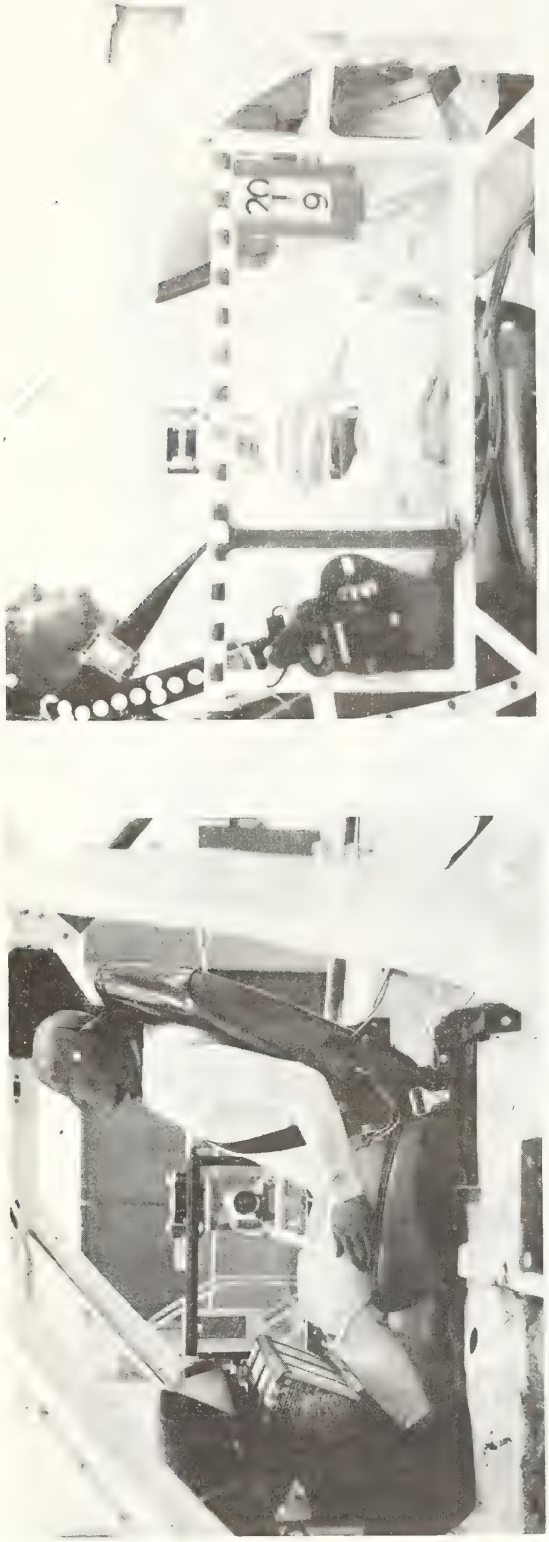
Time = 10 ms/division

RUN 2019 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

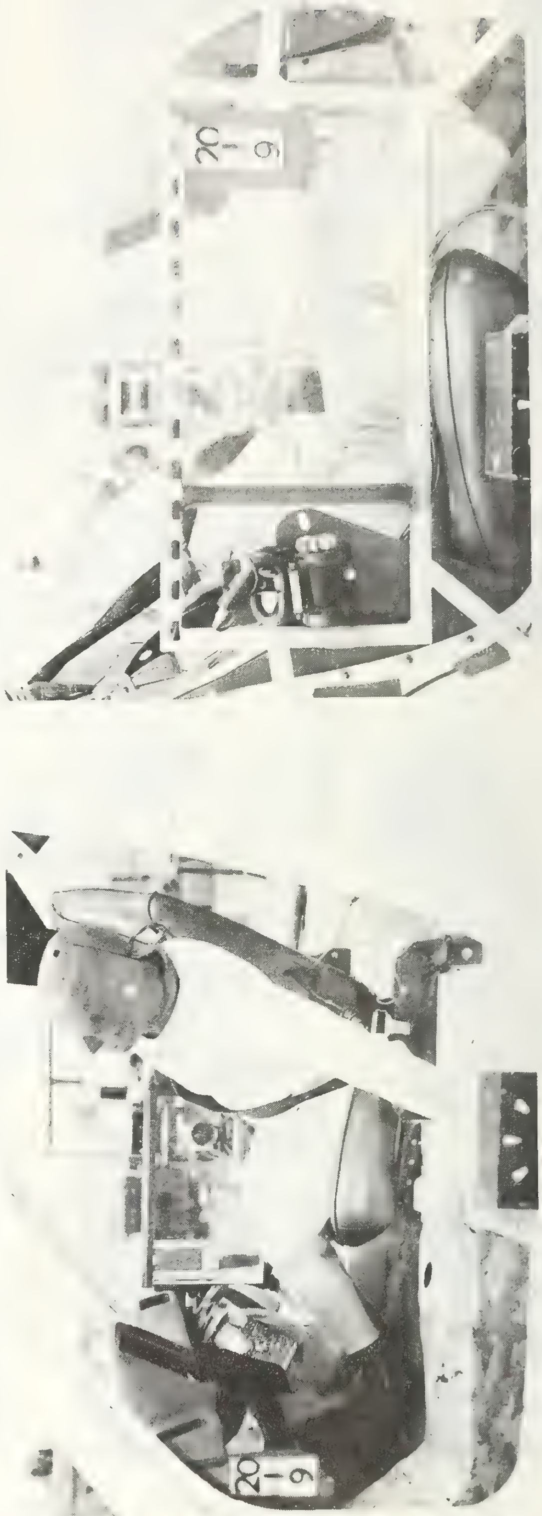


PRETEST

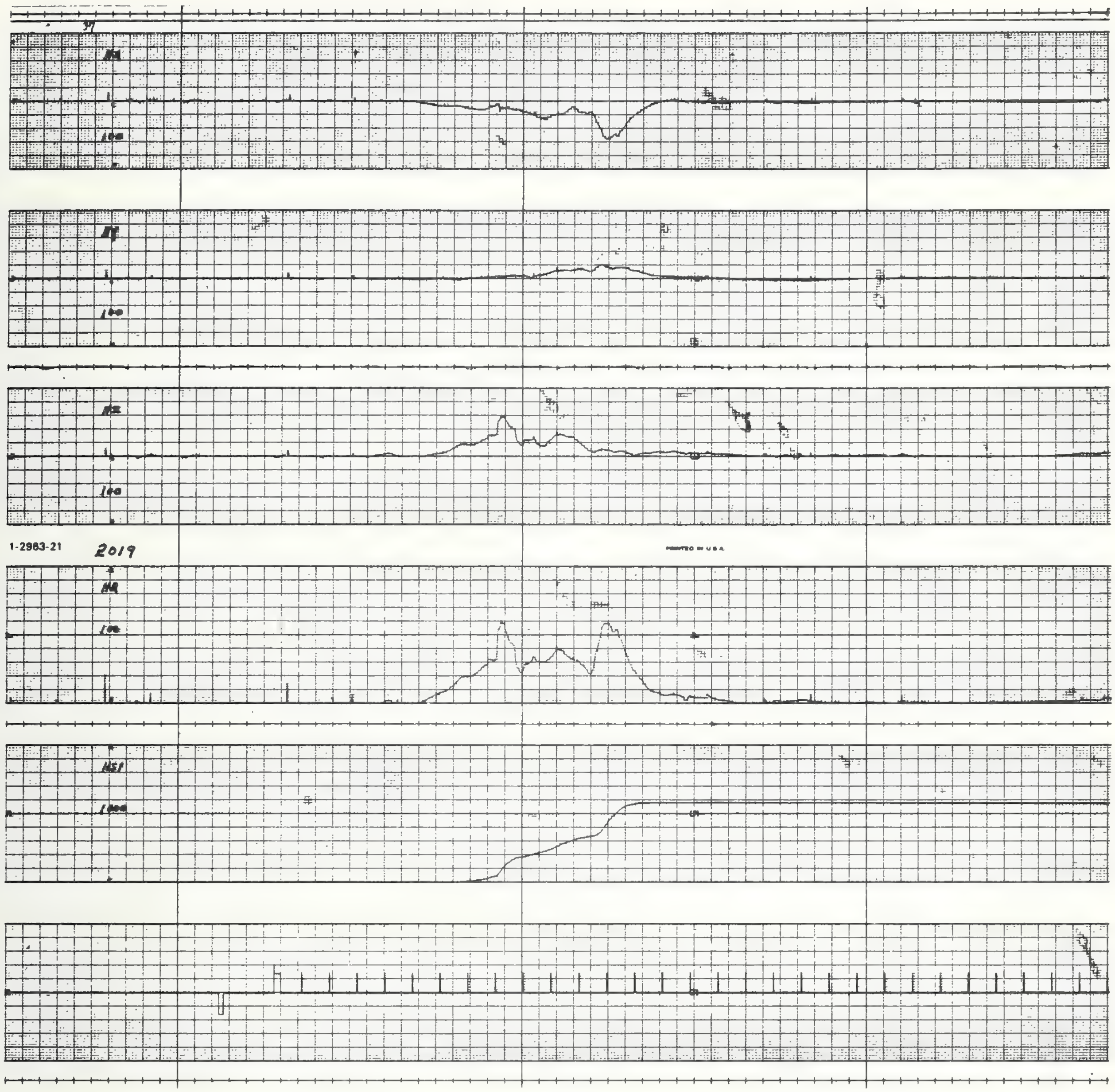
POST TEST
RUN 2019



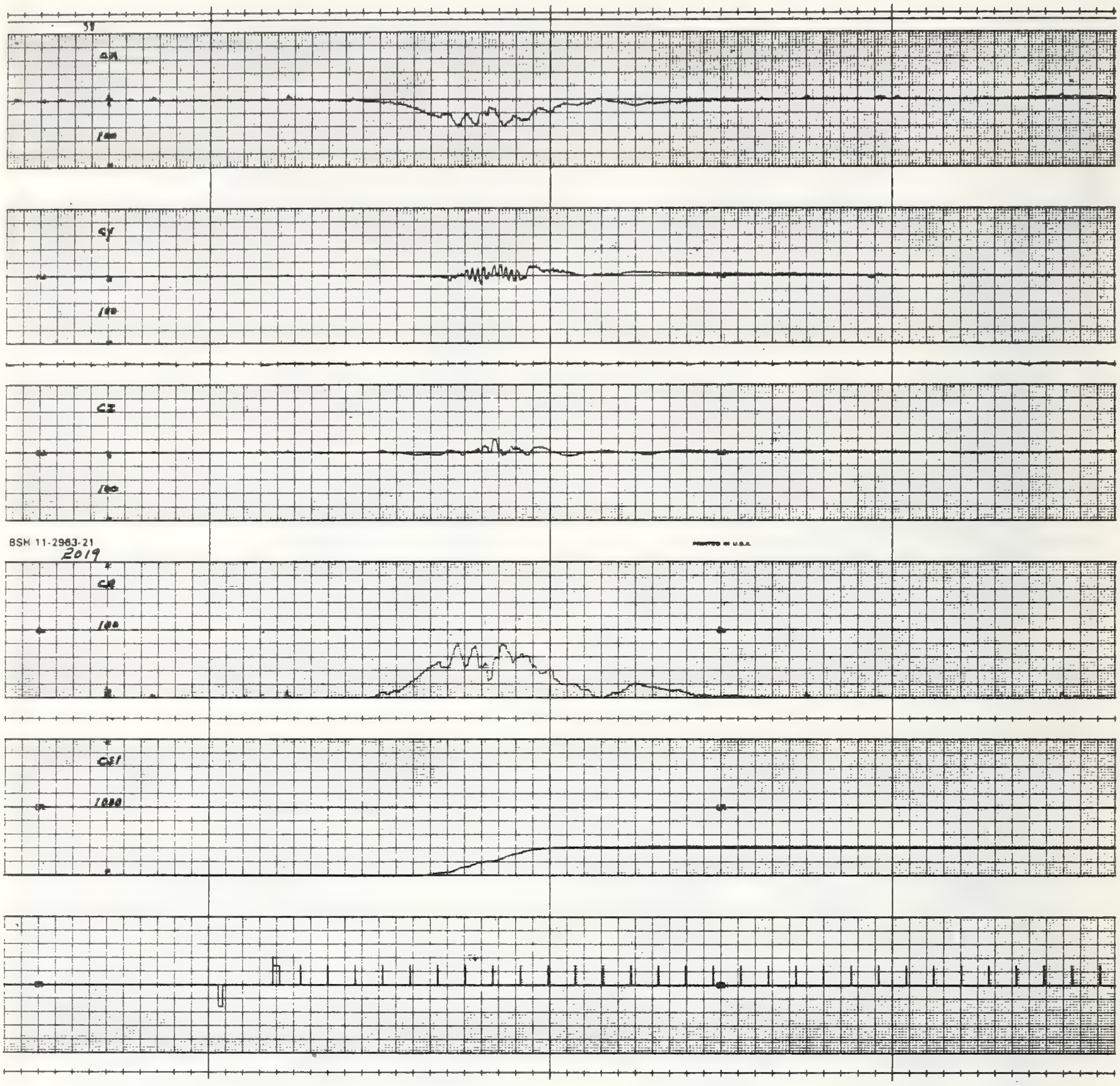
PRETEST



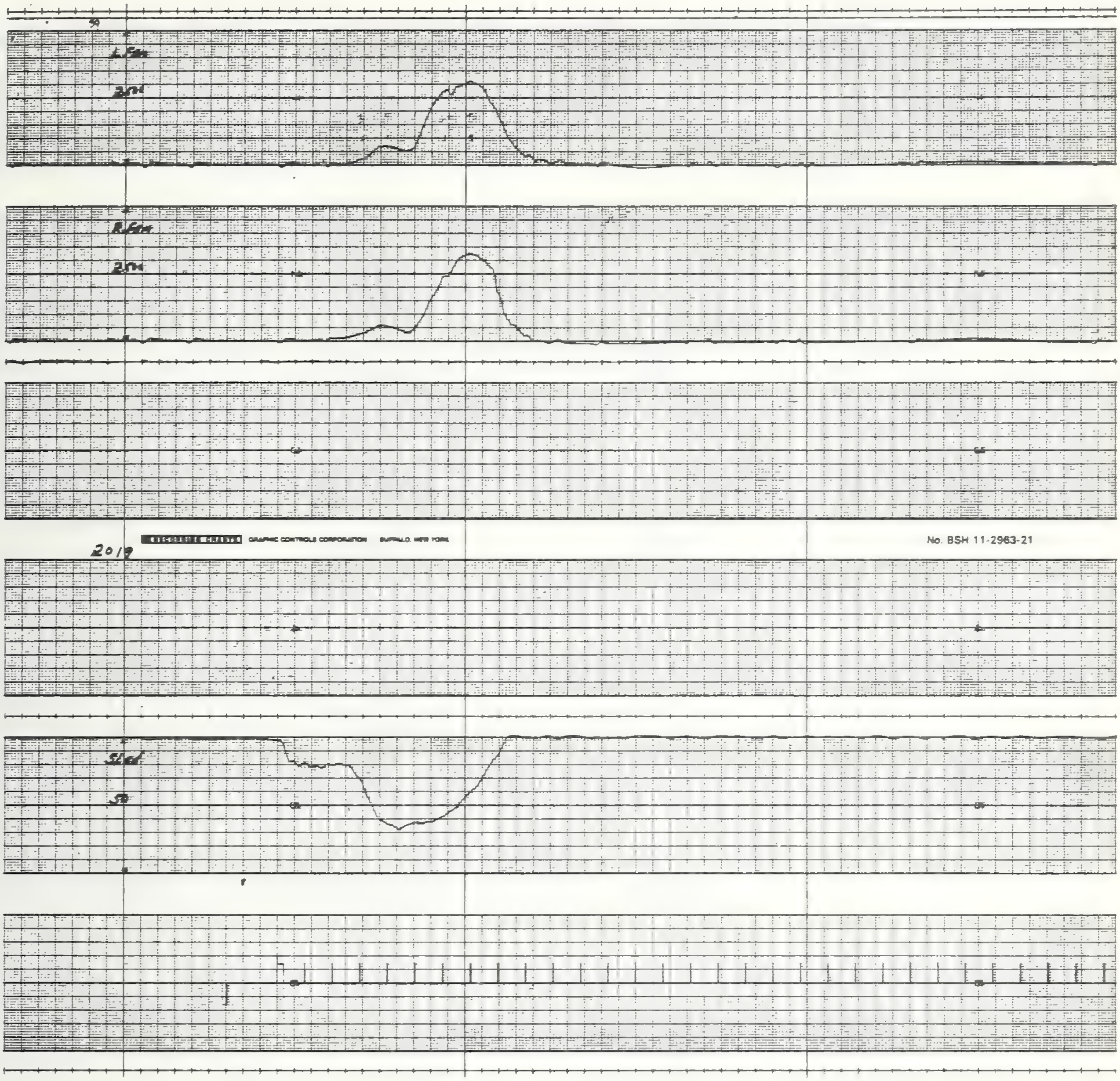
POST TEST
RUN 2019



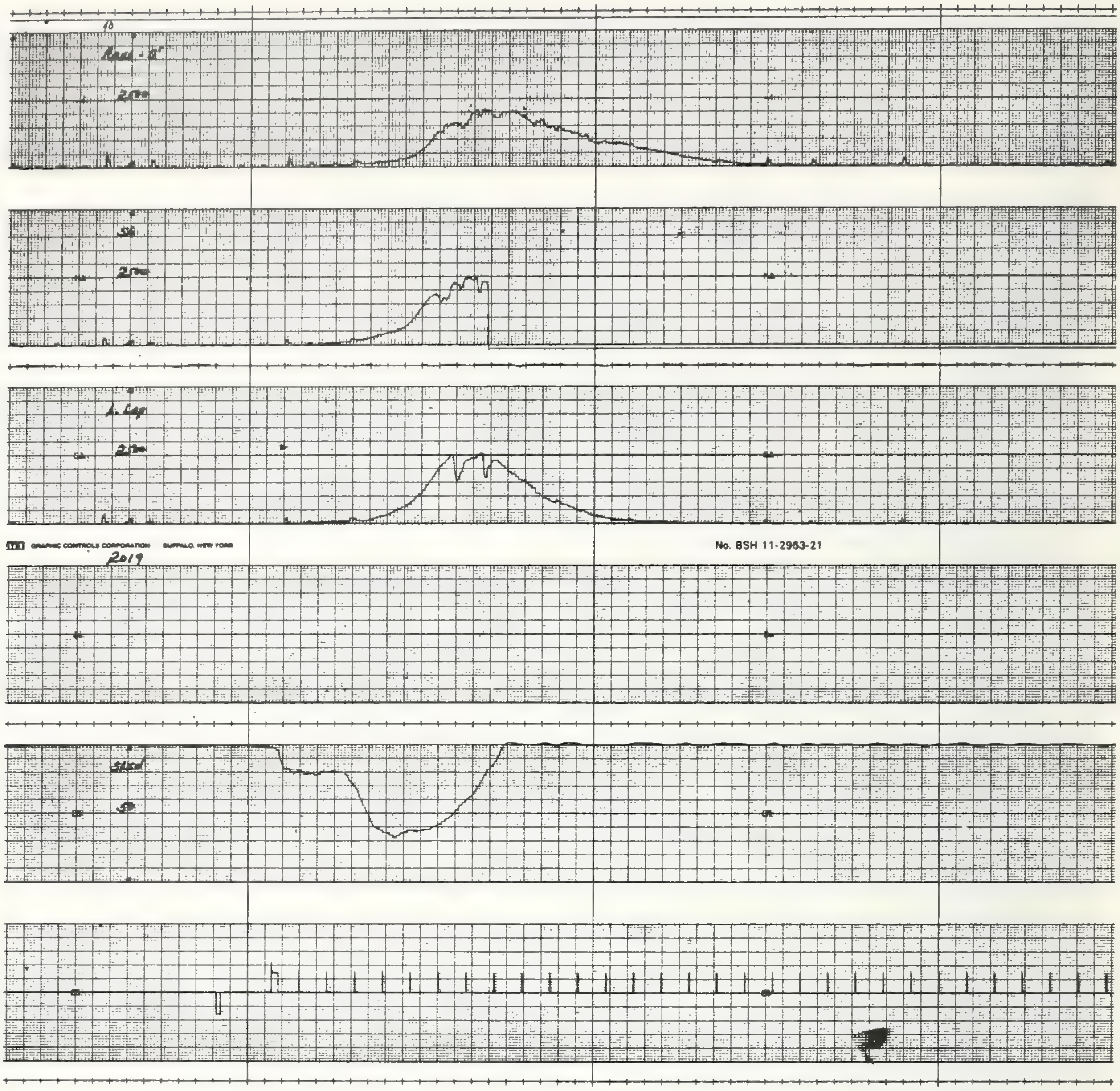
Time = 10 ms/division



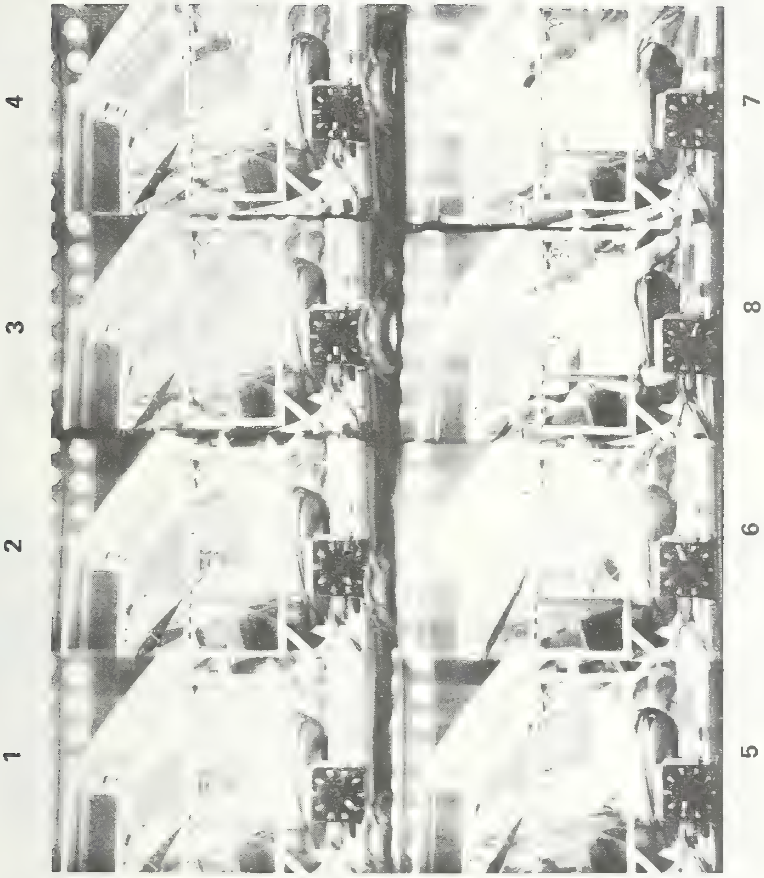
Time = 10 ms/division



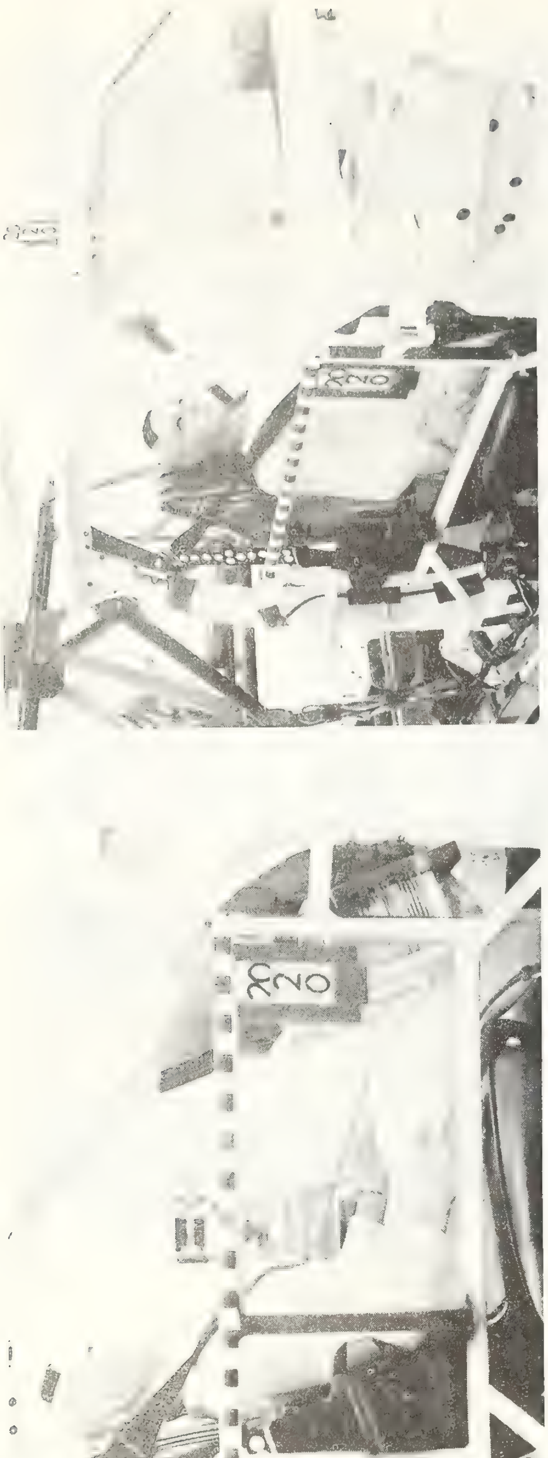
Time = 10 ms/division



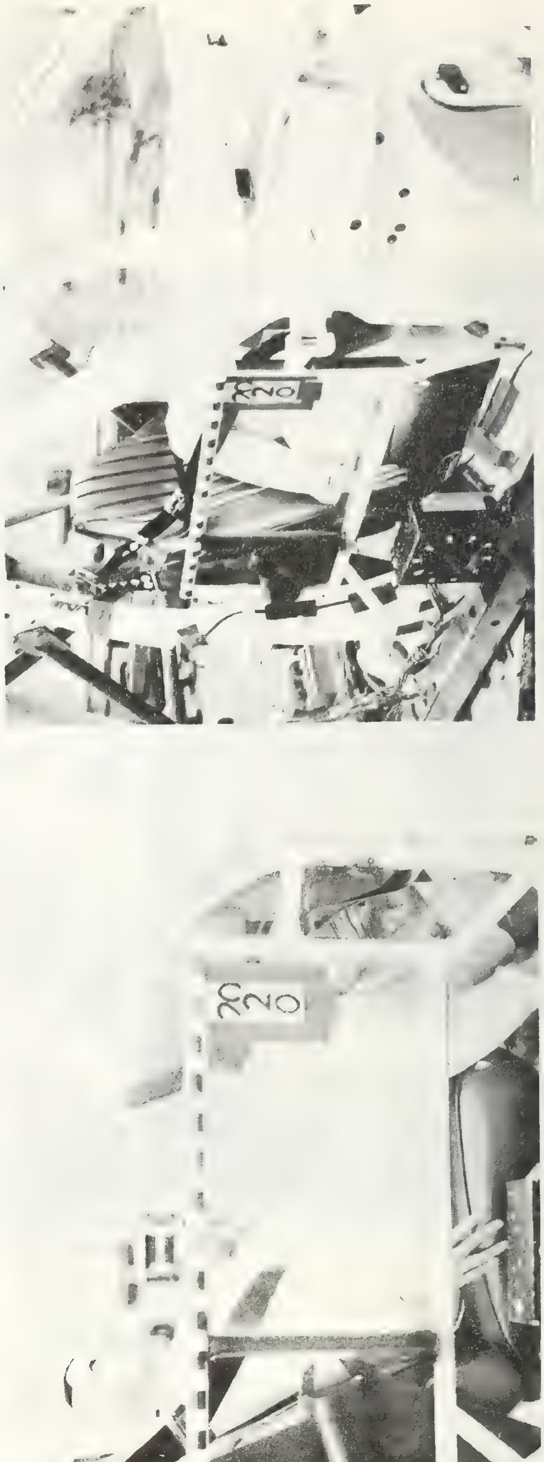
Time = 10 ms/division



RUN 2020 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

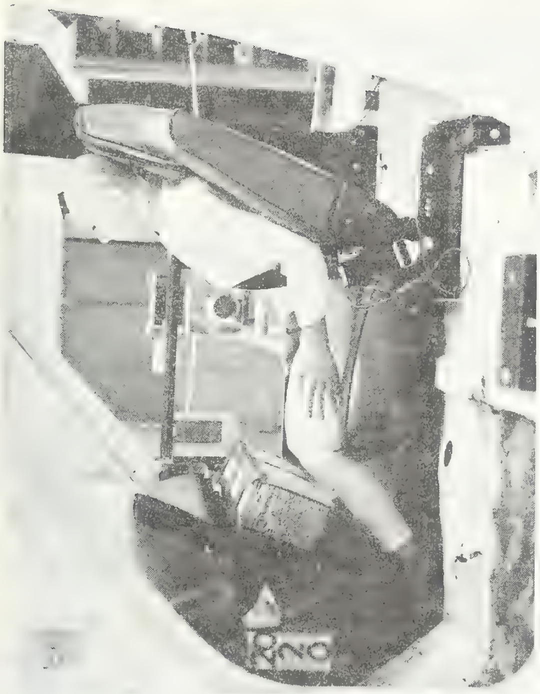


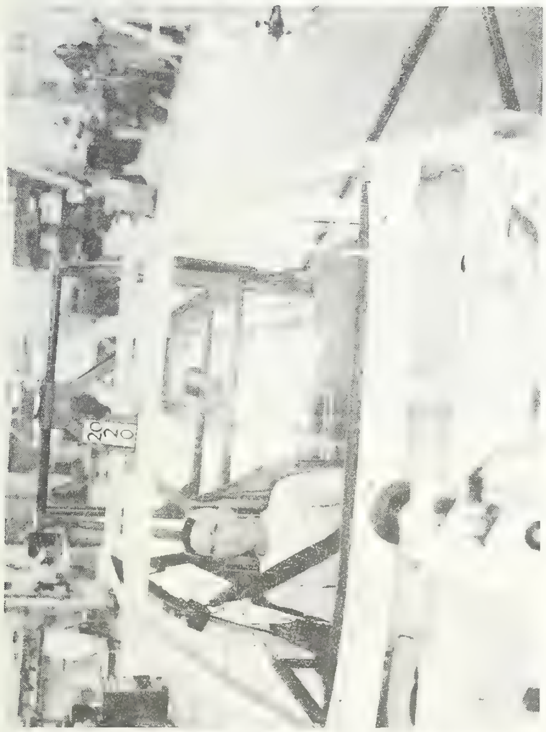
PRETEST



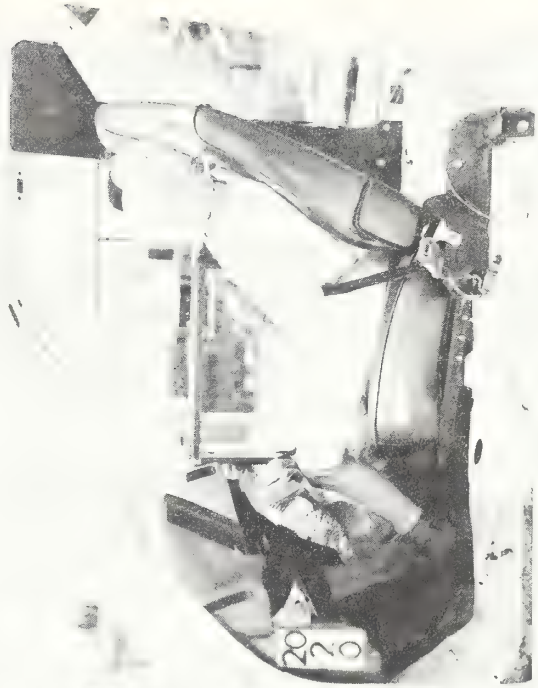
POST TEST

RUN 2020

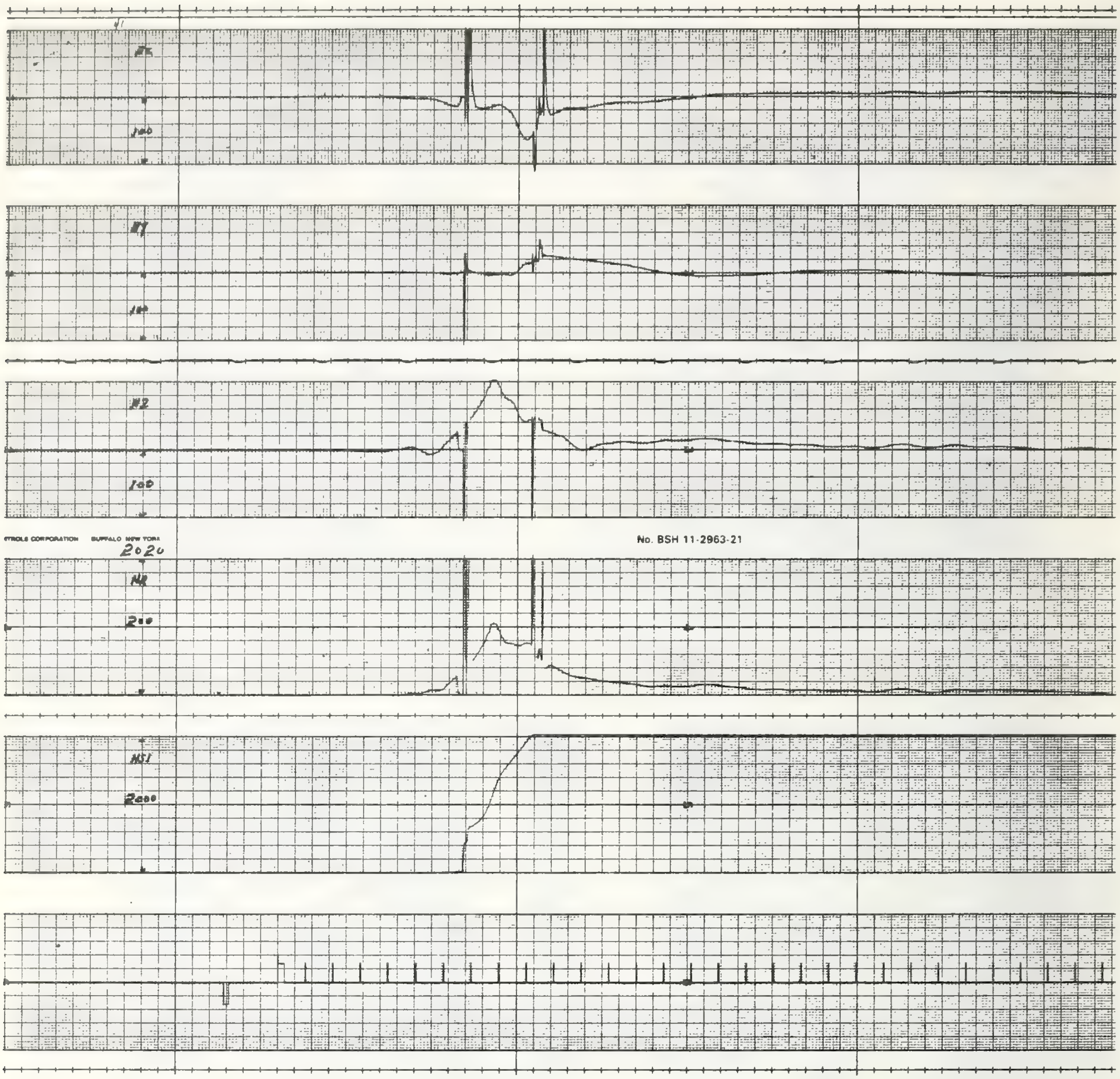




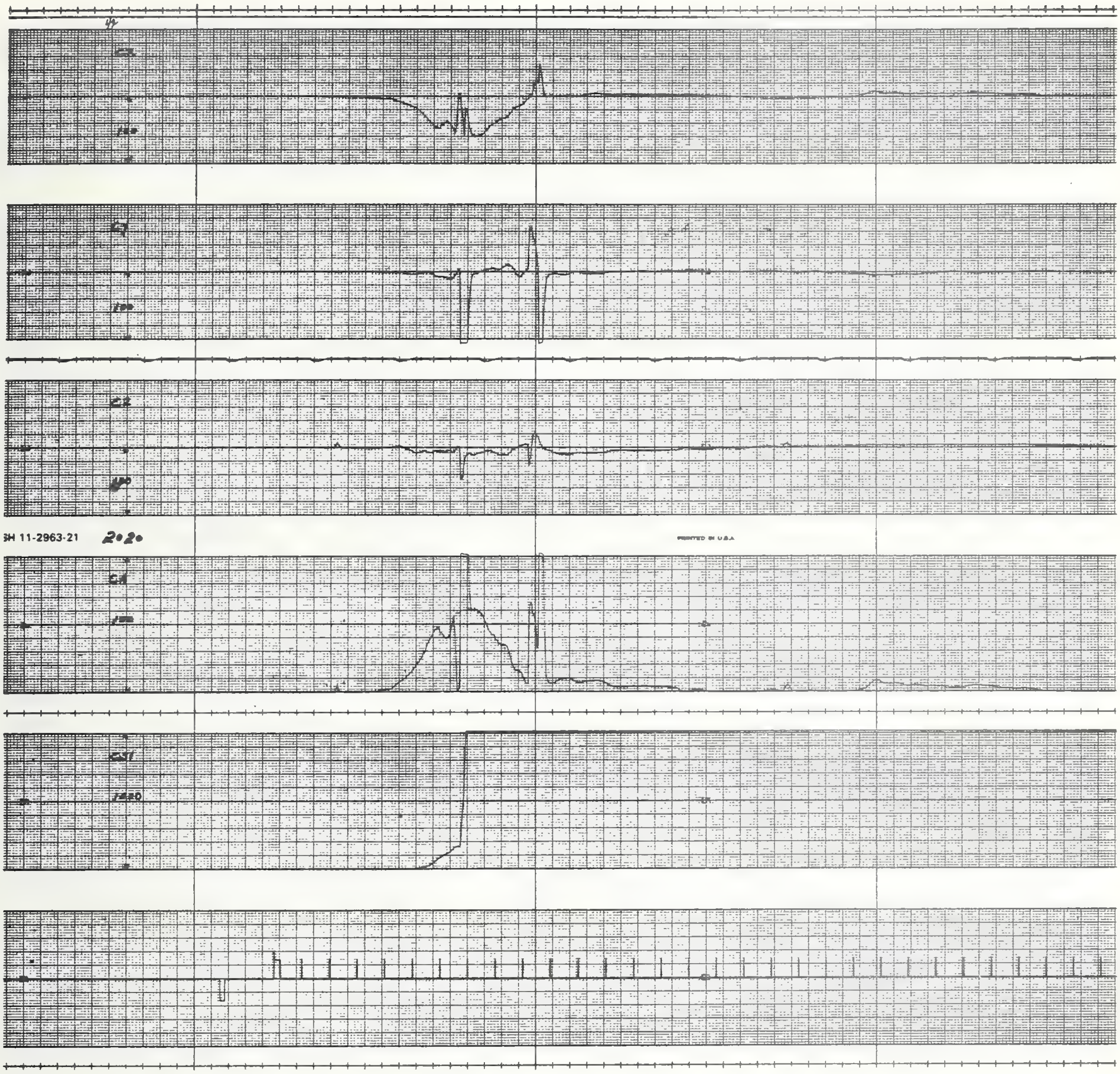
PRETEST



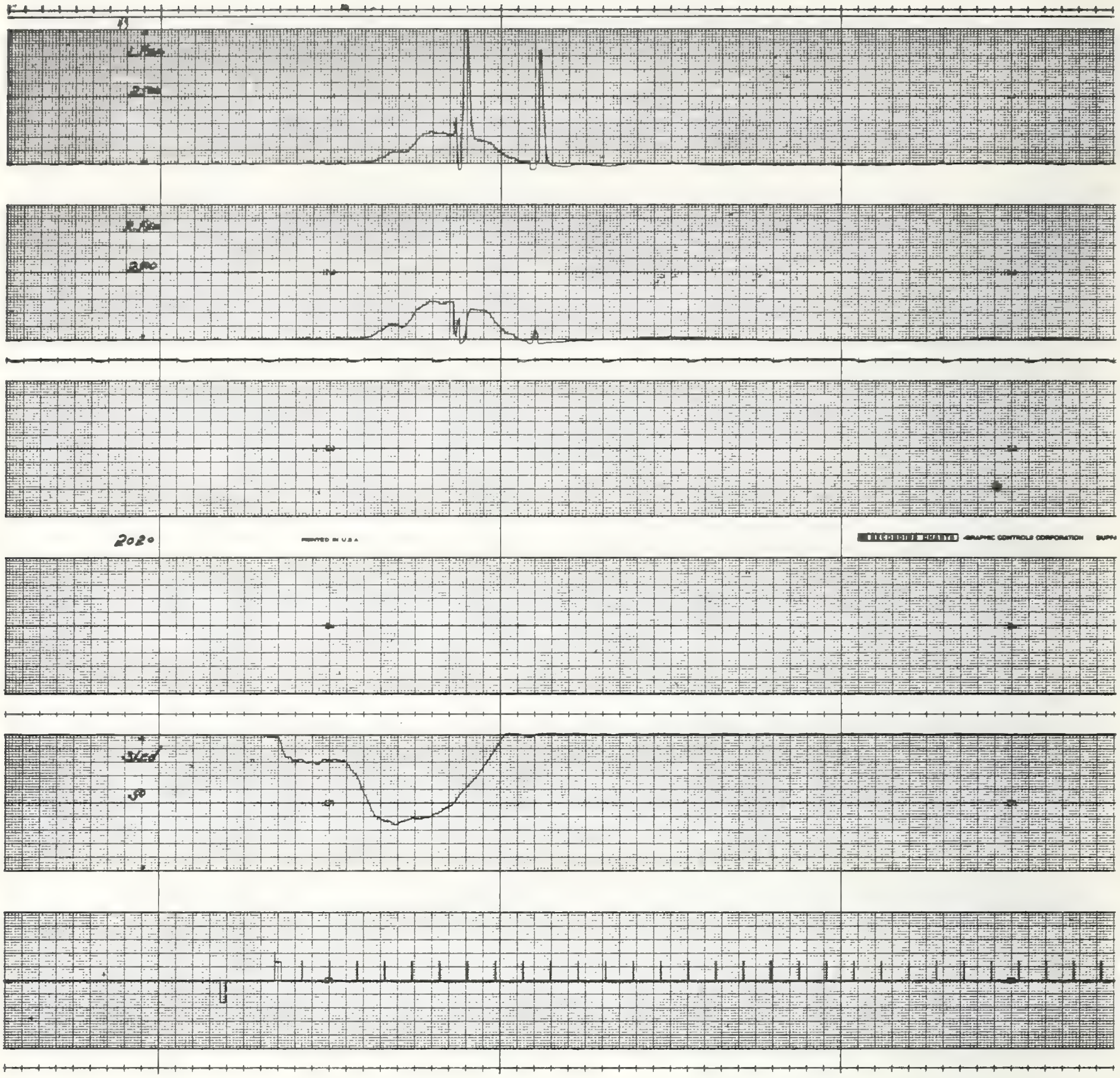
POST TEST
RUN 2020



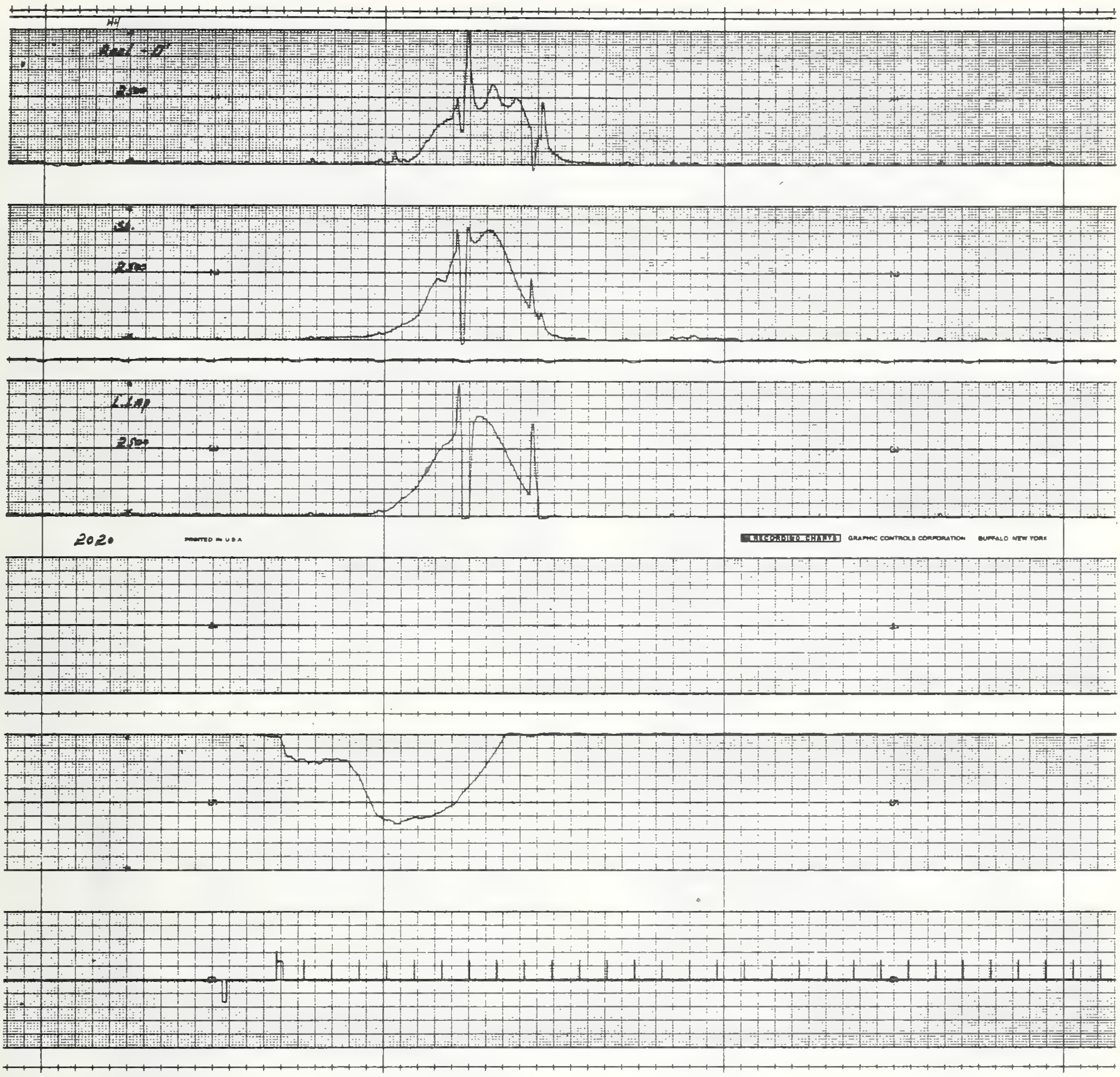
Time = 10 ms/division



Time = 10 ms/division



Time = 10 ms/division



Time = 10 ms/division

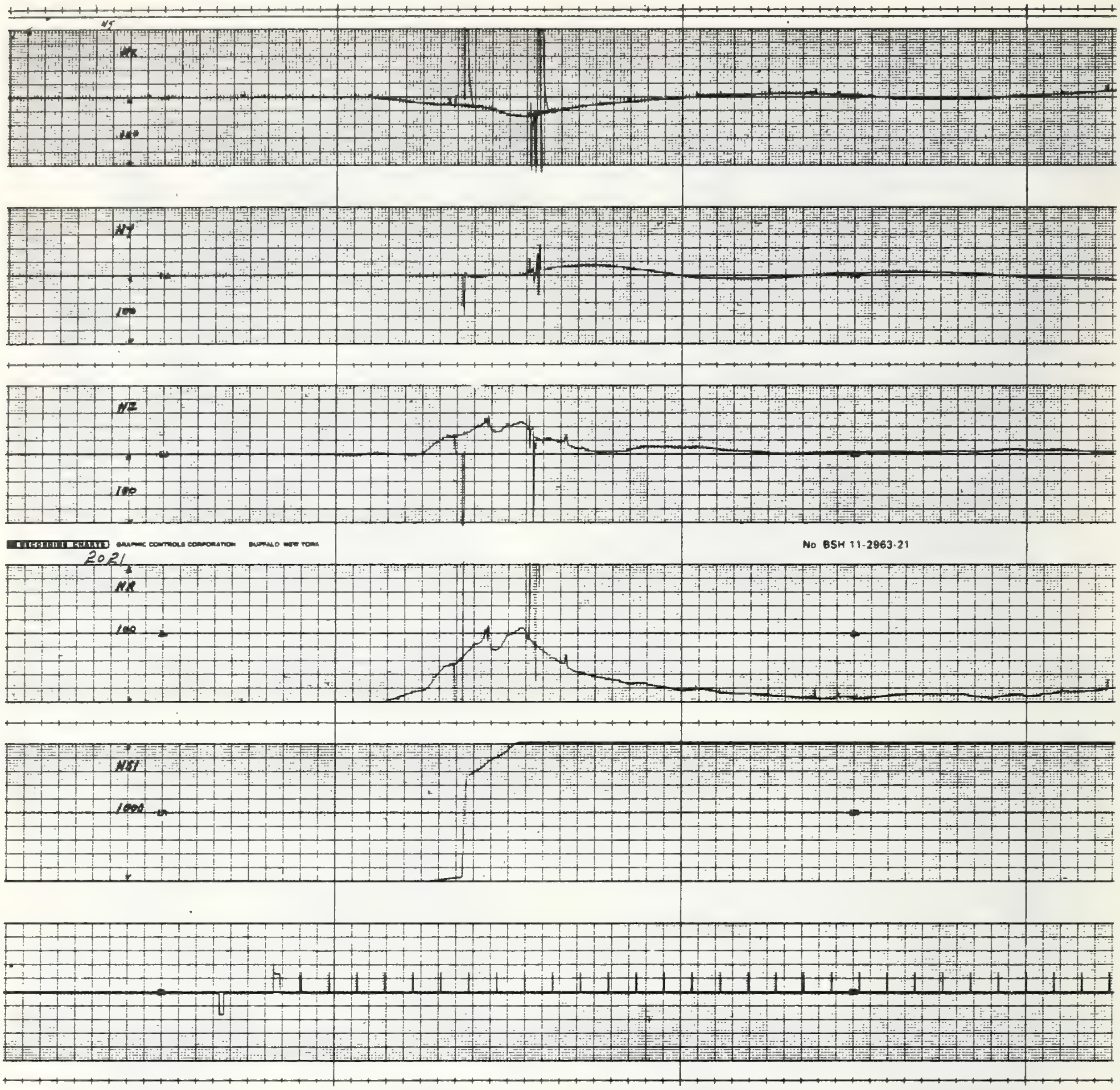
PRETEST

POST TEST

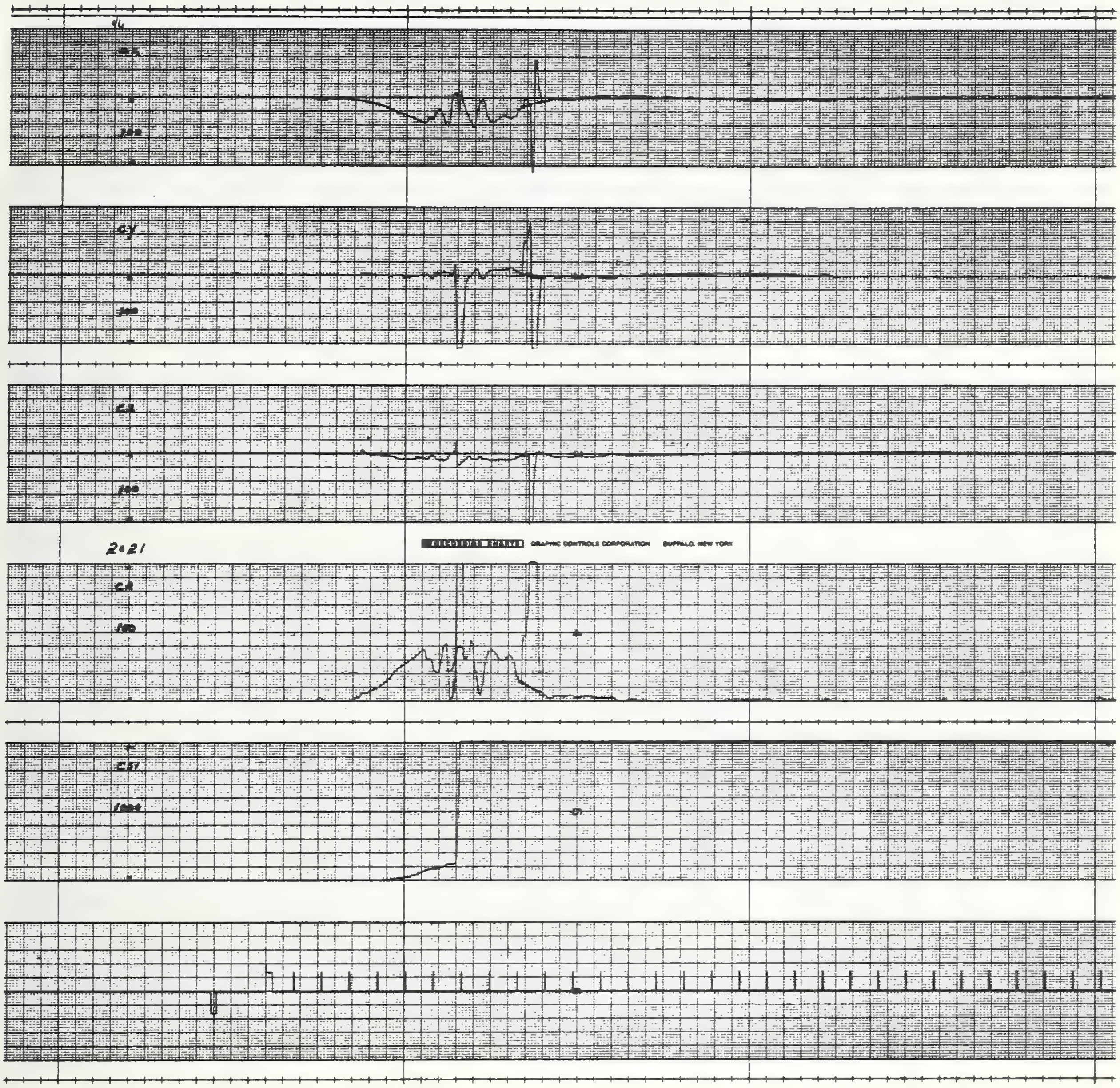
RUN 2021

PRETEST

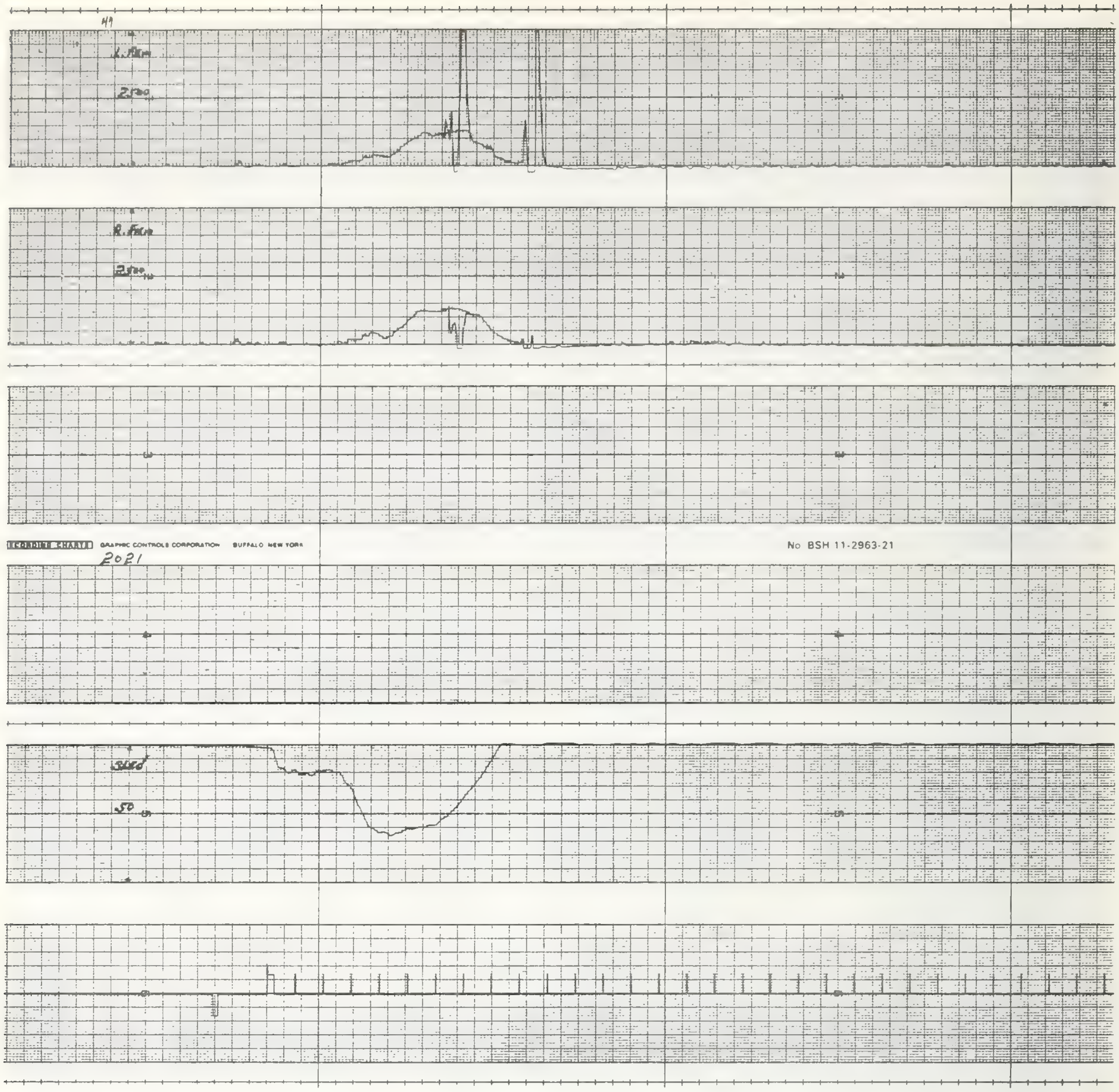
POST TEST
RUN 2021



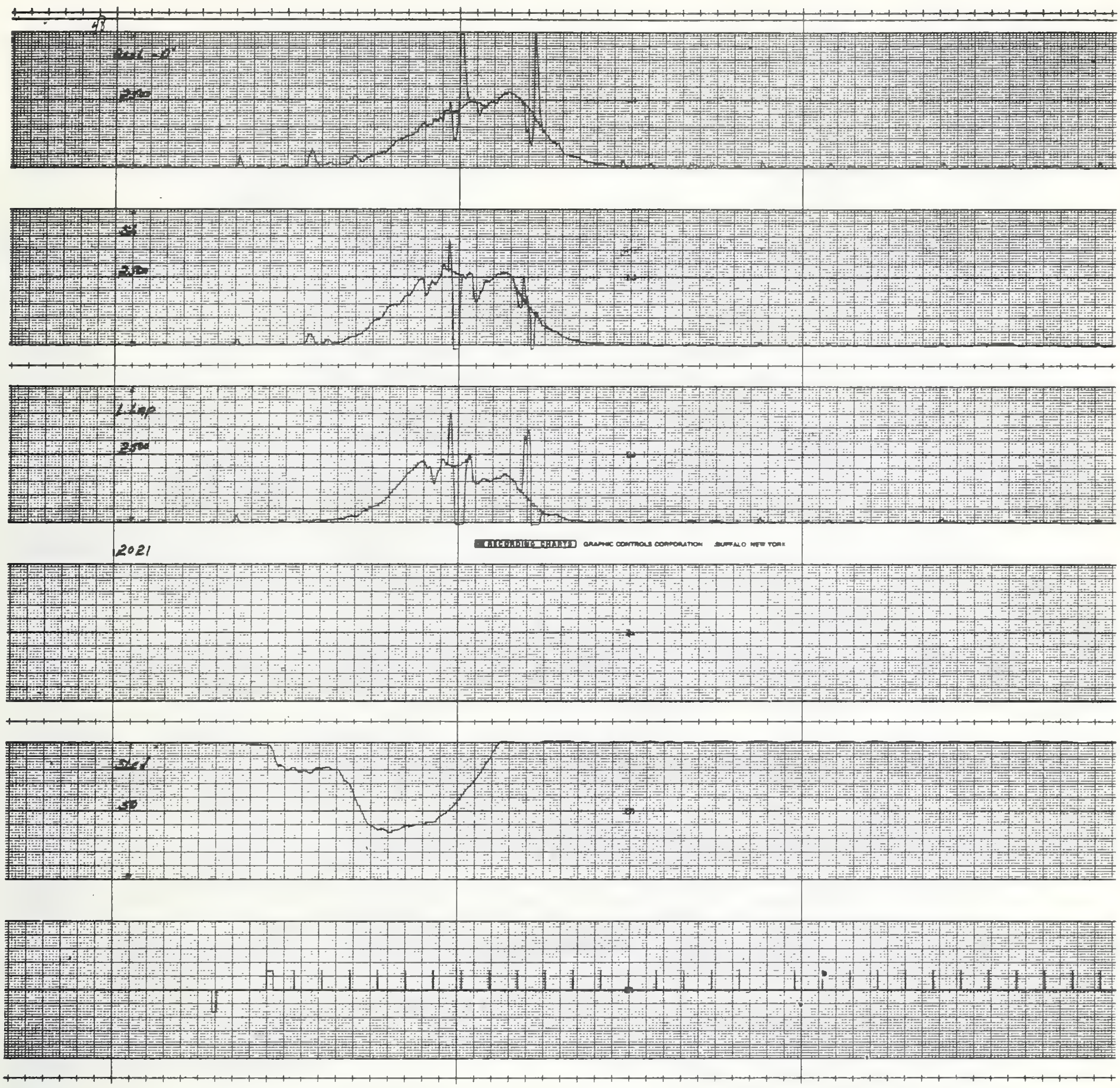
Time = 10 ms/division



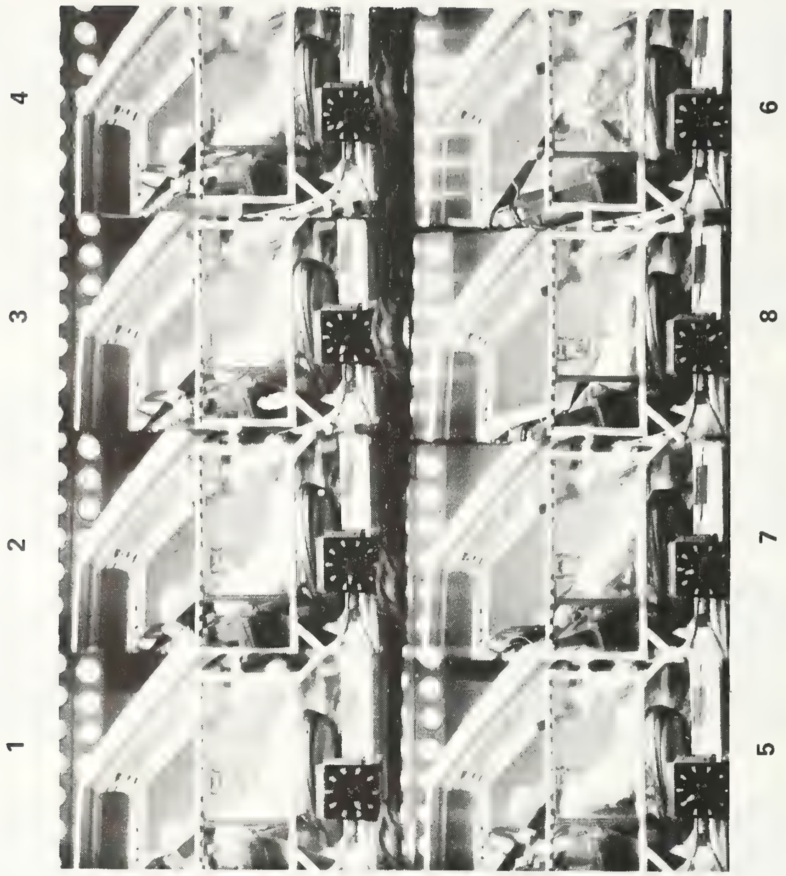
Time = 10 ms/division



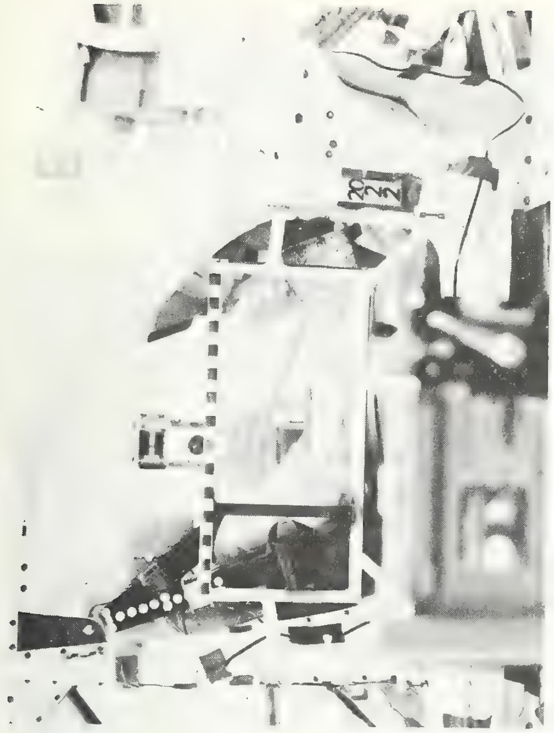
Time = 10 ms/division



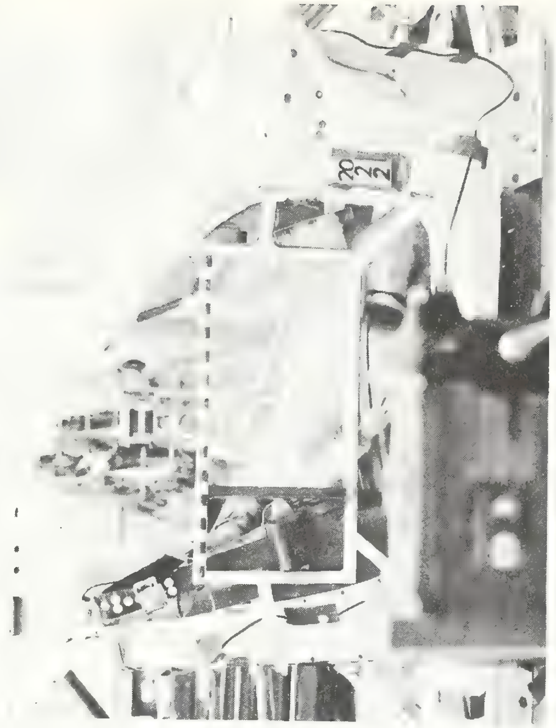
Time = 10 ms/division

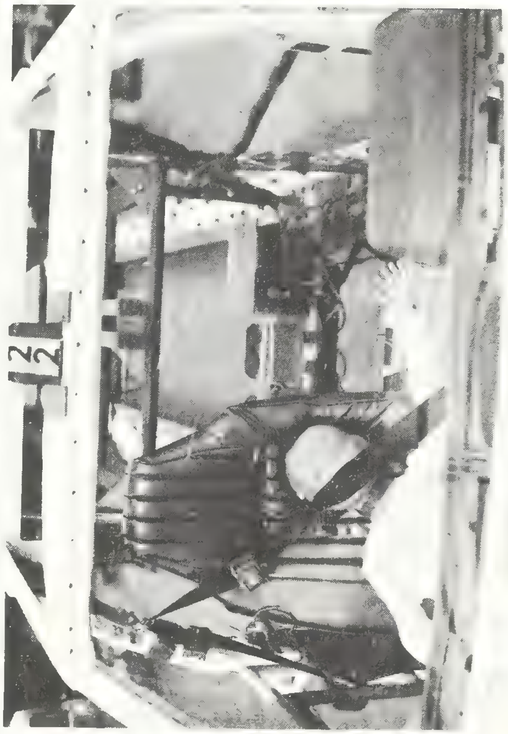


RUN 2022 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION



PRETEST

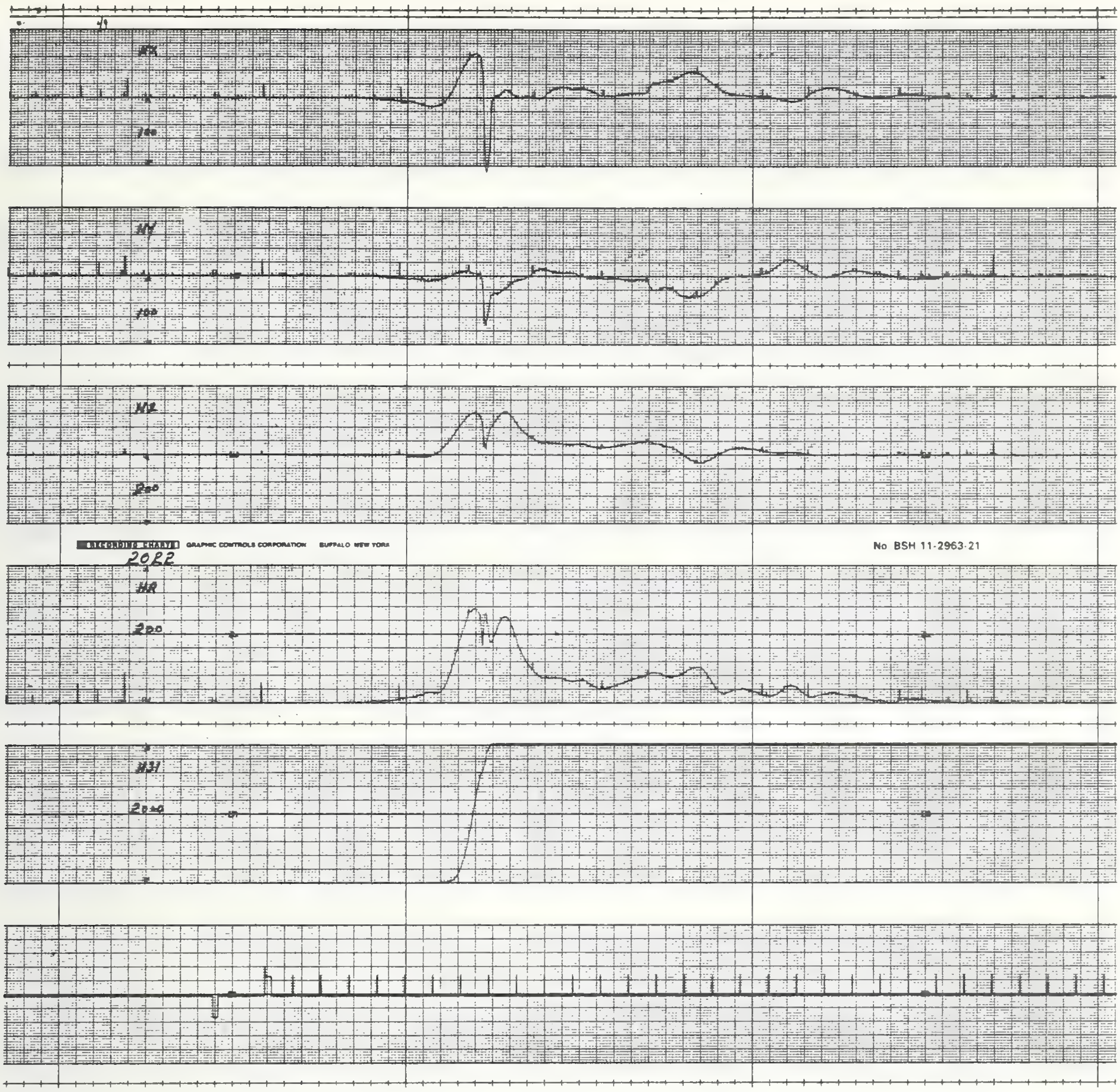




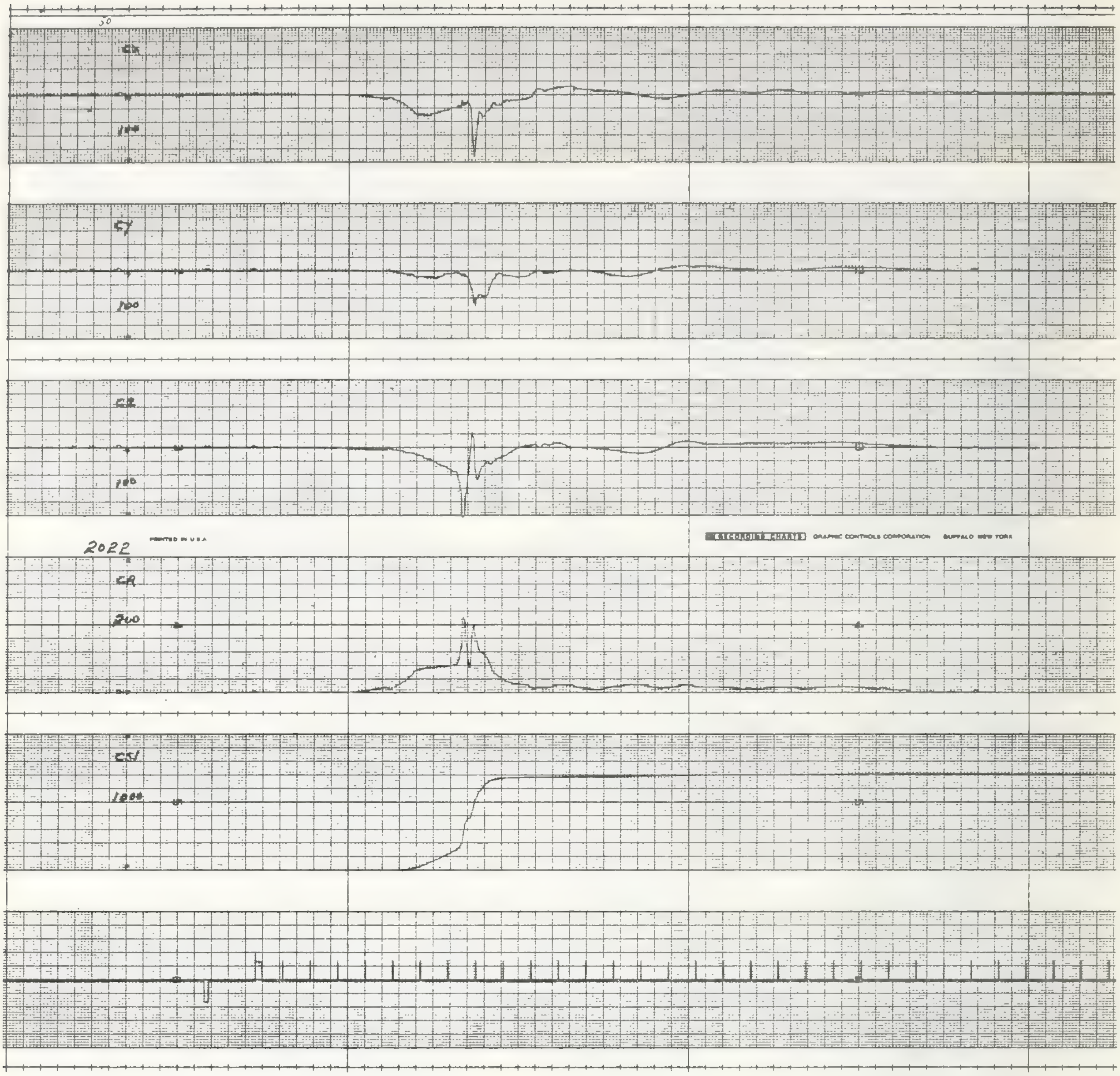
POST TEST
RUN 2022

PRETEST

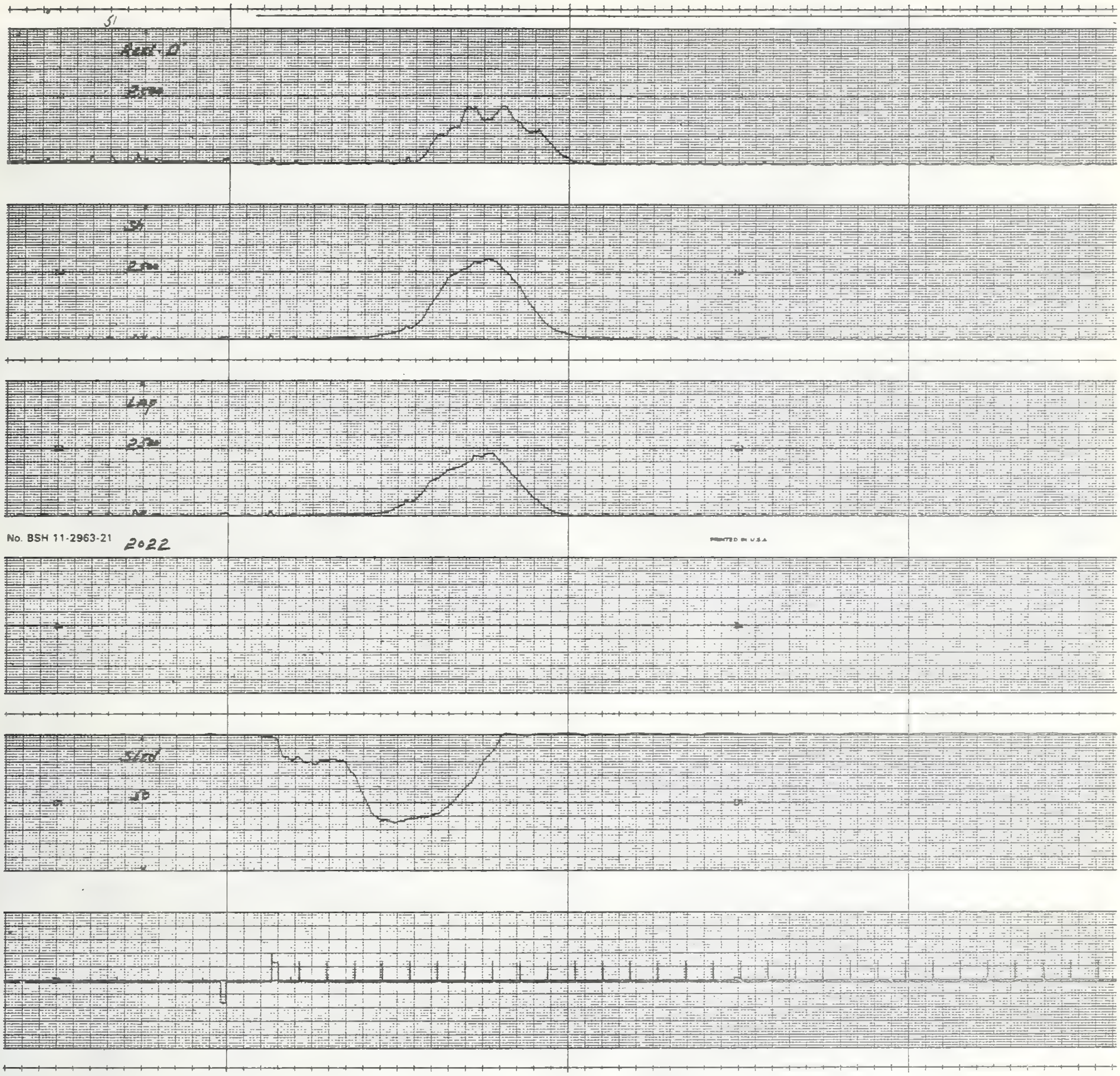
POST TEST
RUN 2022



Time = 10 ms/division

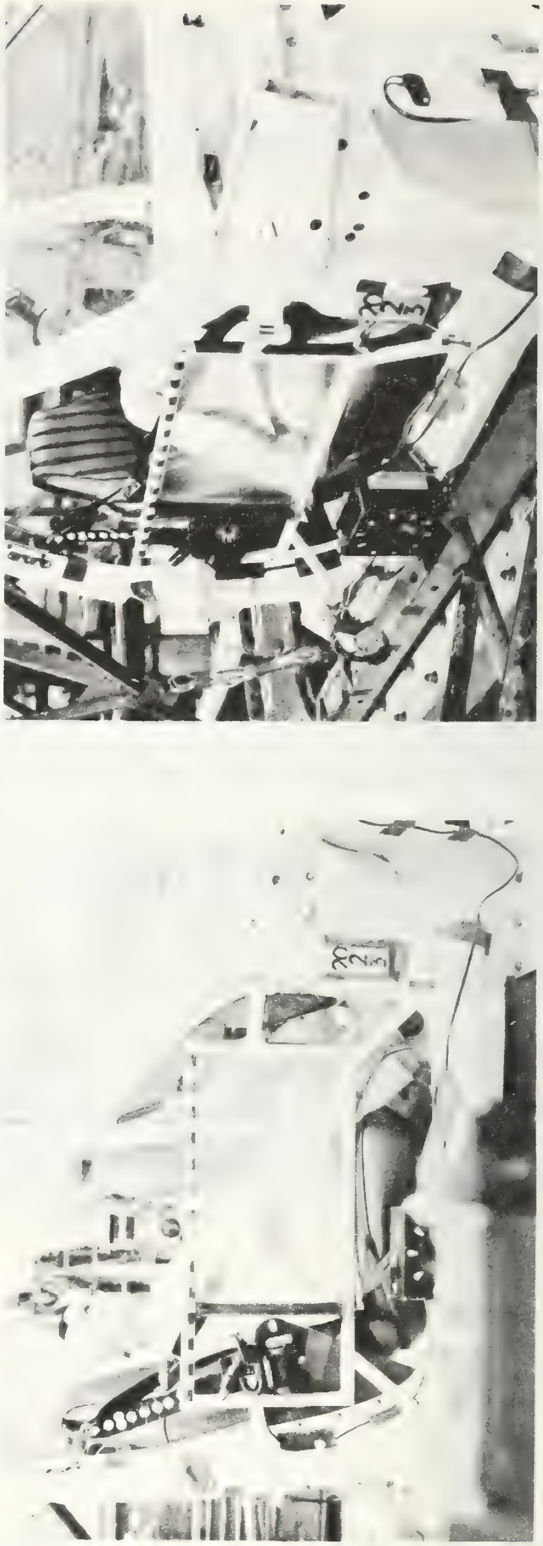


Time = 10 ms/division



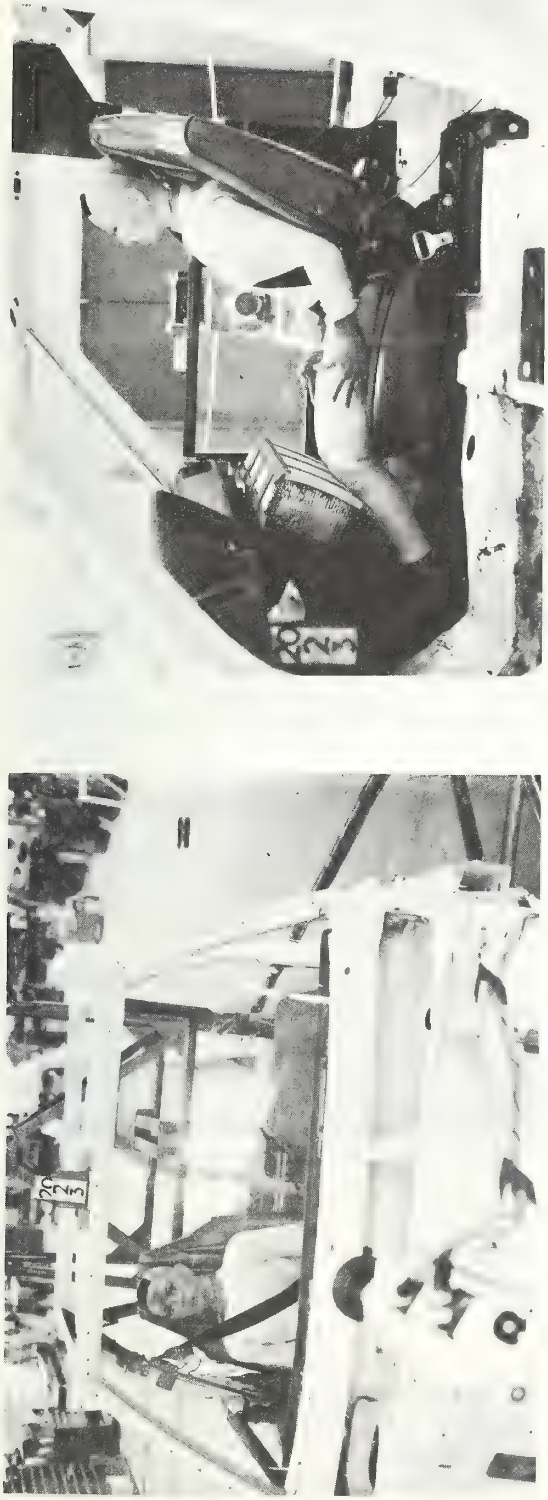
Time = 10 ms/division

PRETEST



POST TEST

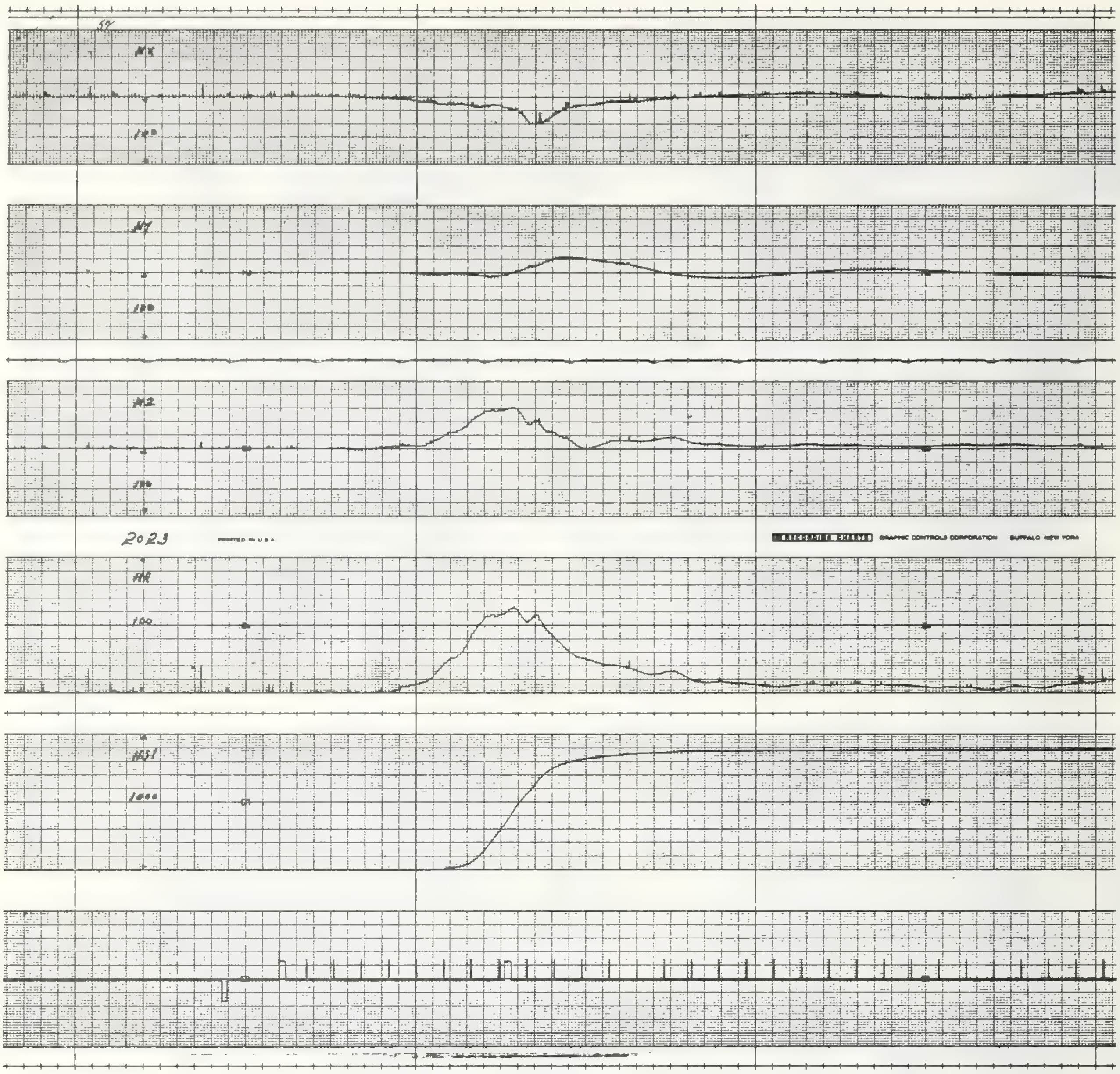
RUN 2023



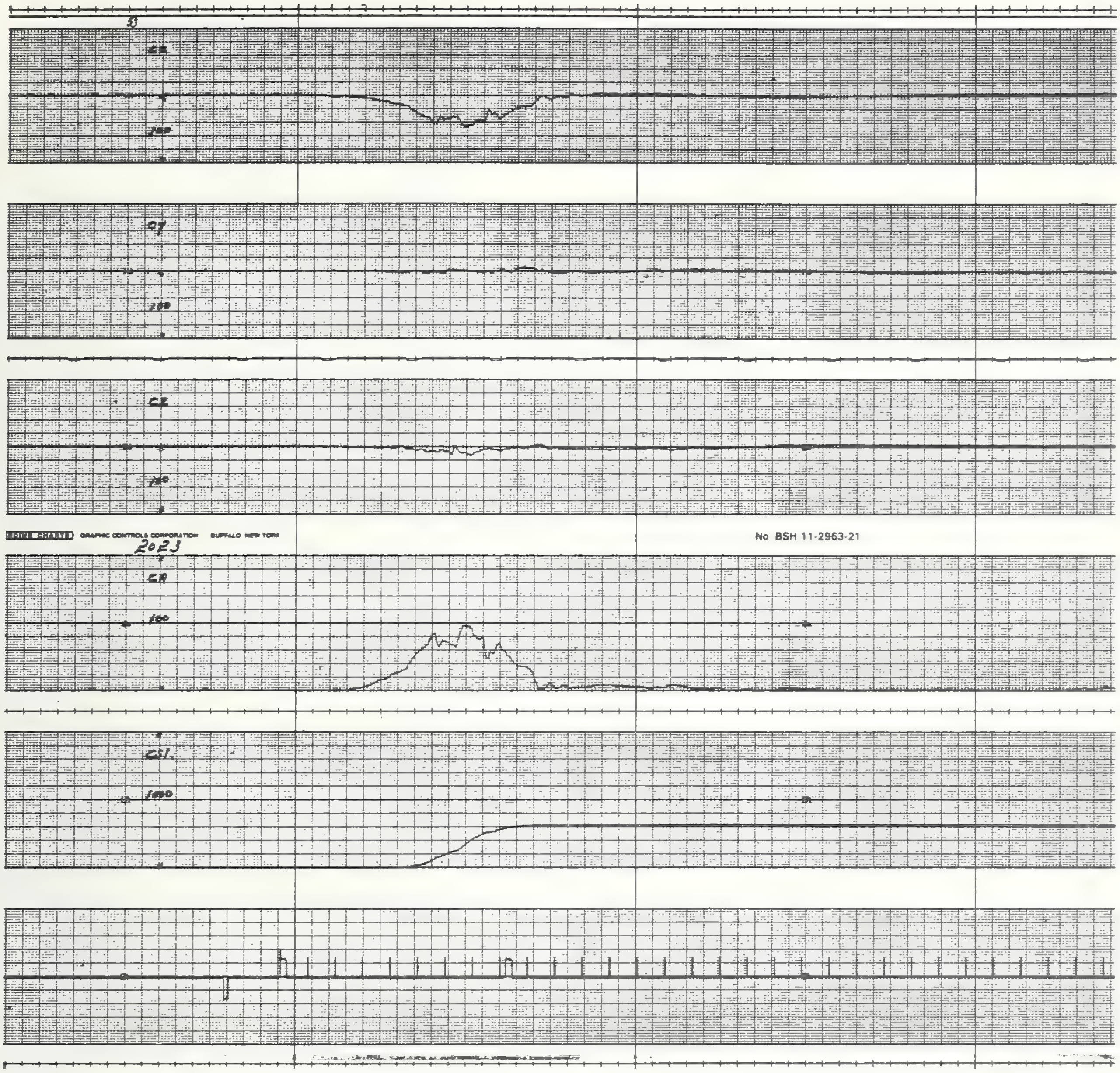
PRETEST

POST TEST

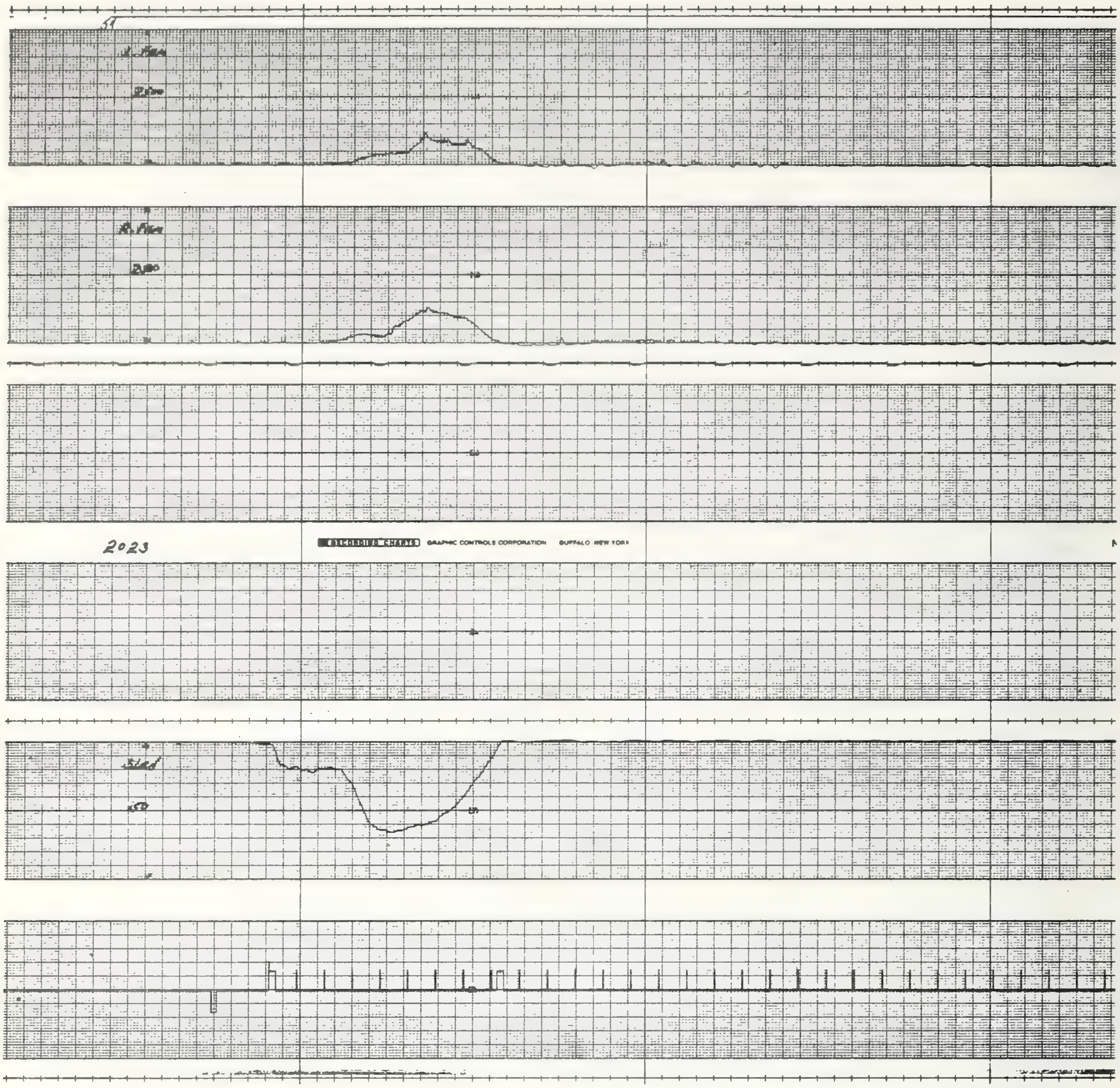
RUN 2023



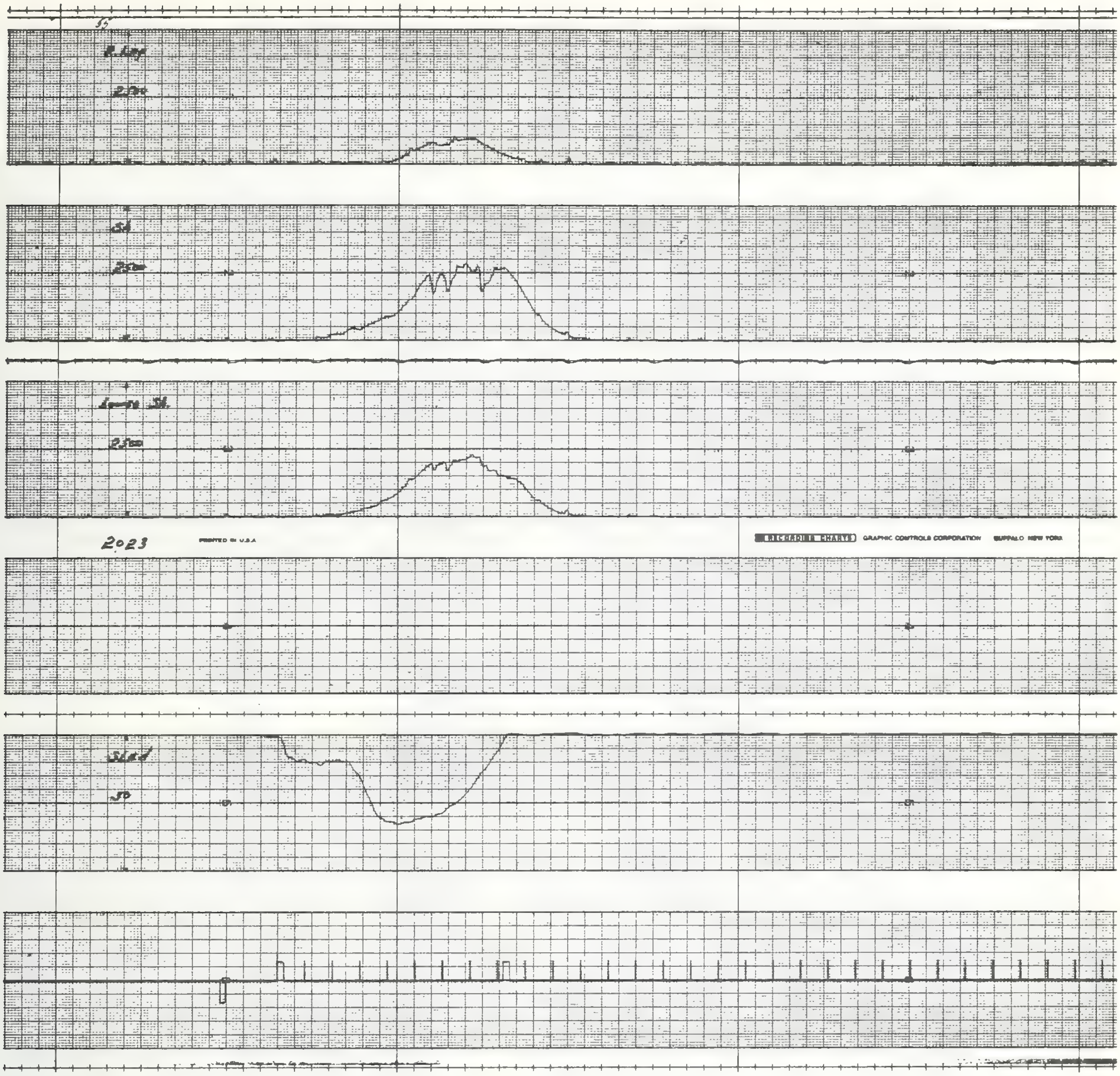
Time = 10 ms/division



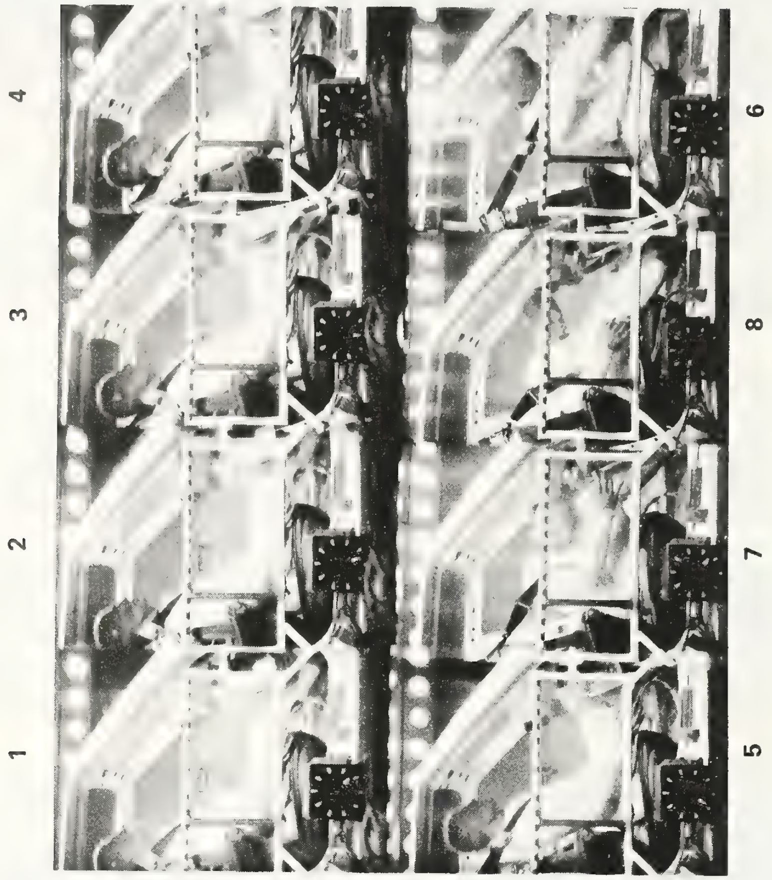
Time = 10 ms/division



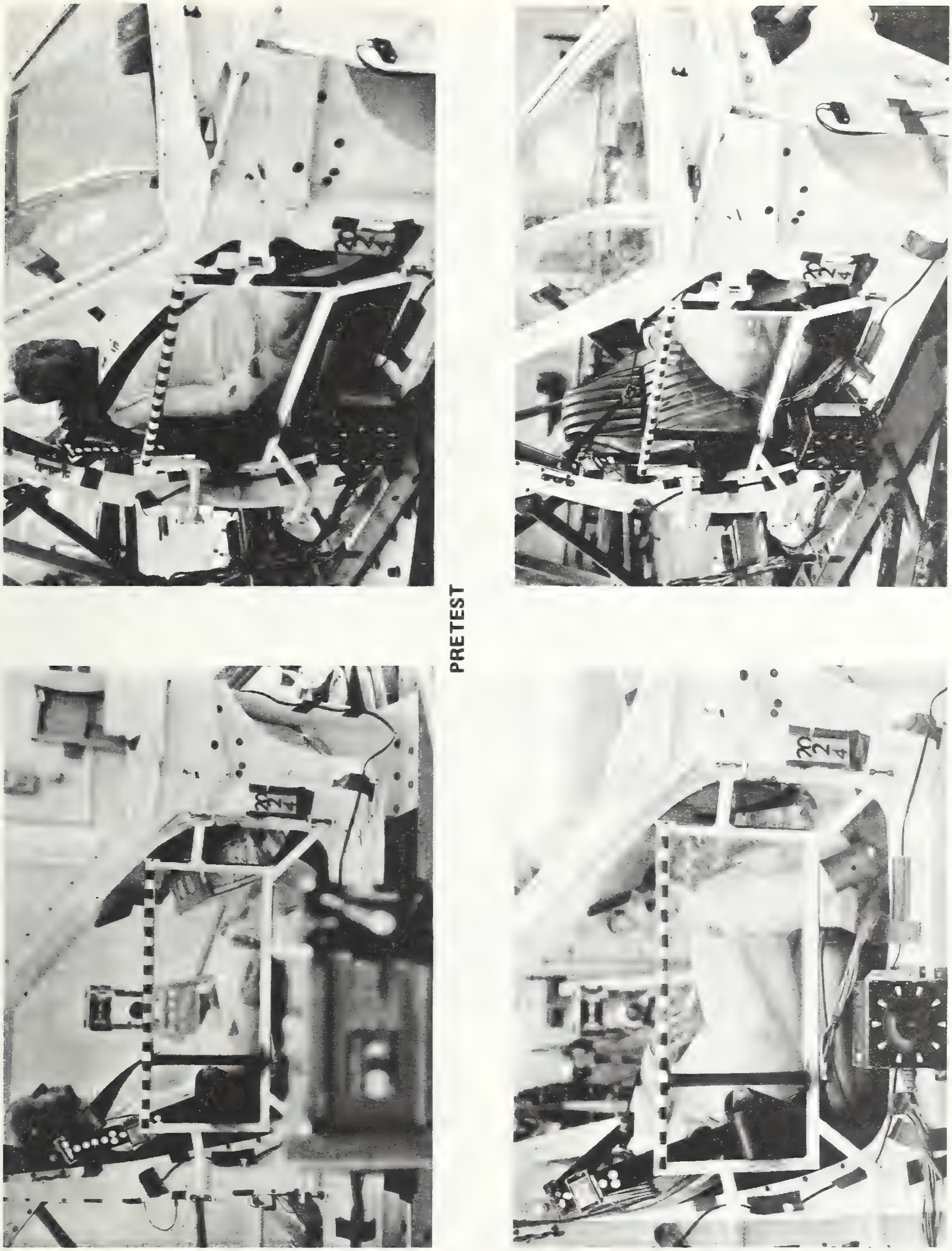
Time = 10 ms division



Time = 10 ms/division



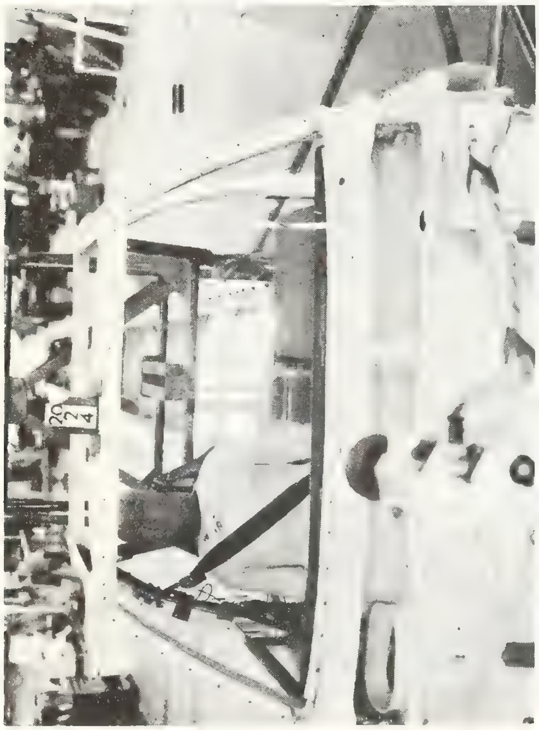
RUN 2024 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION



PRETEST

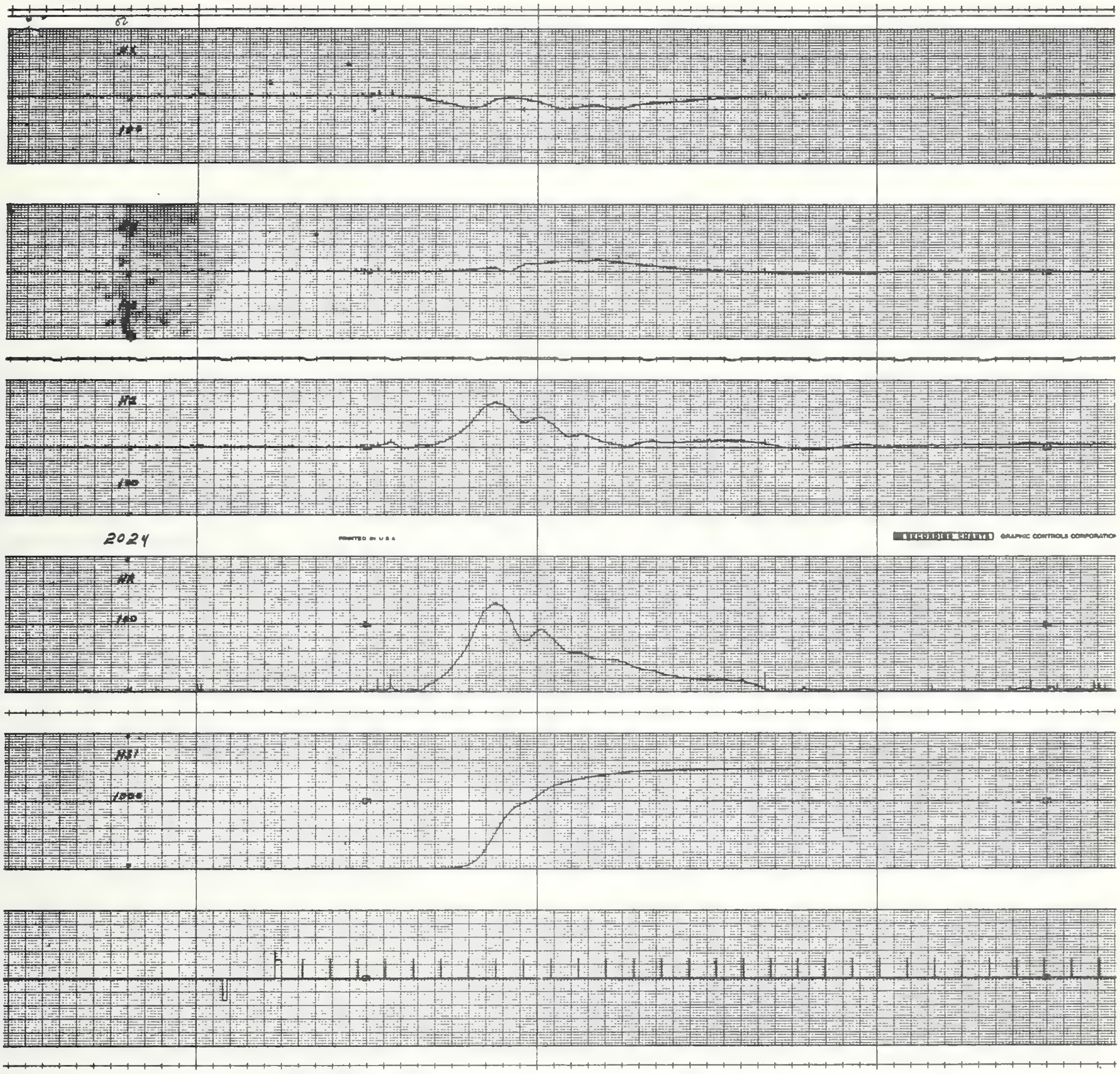
POST TEST

RUN 2024

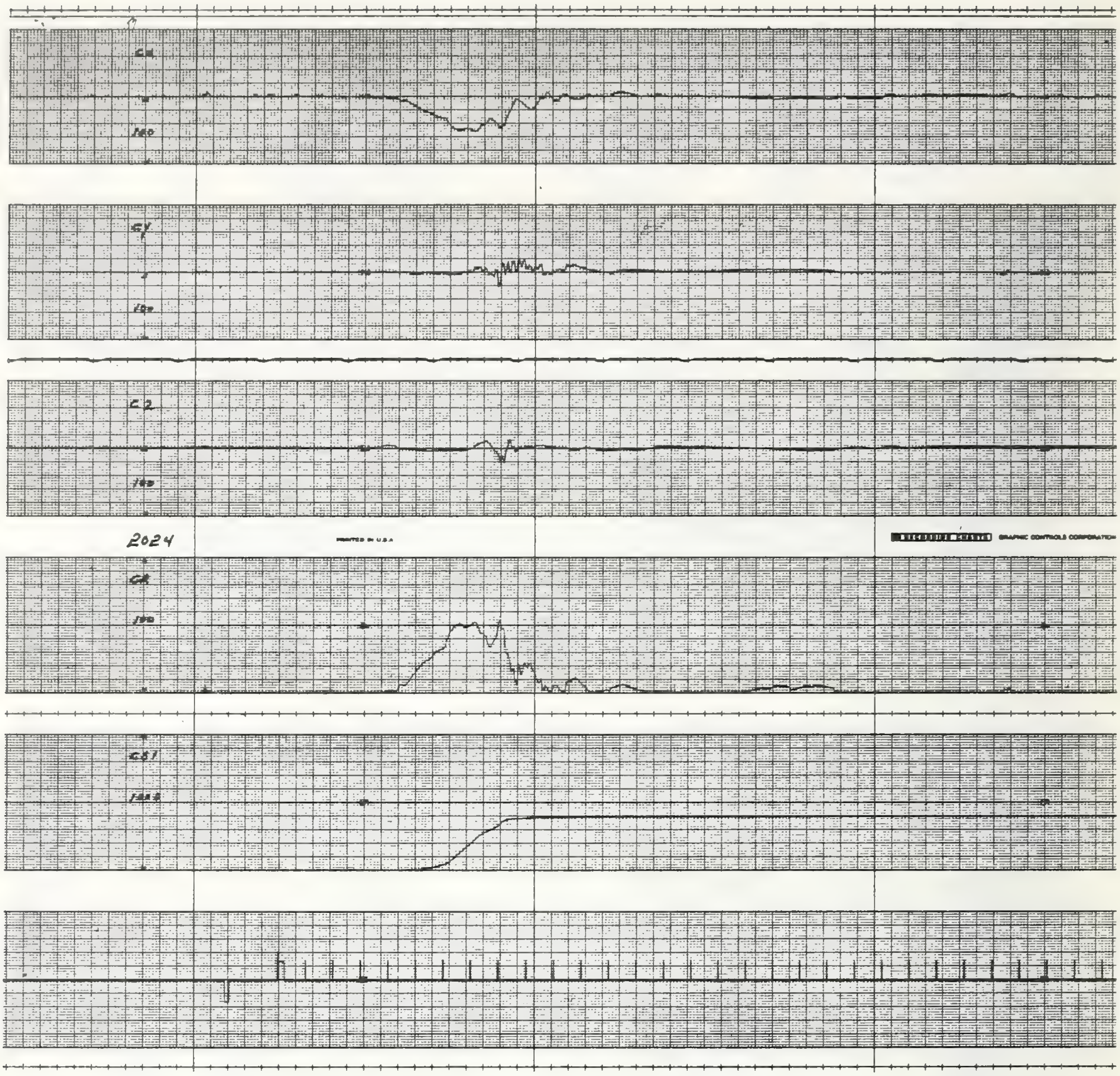


PRETEST

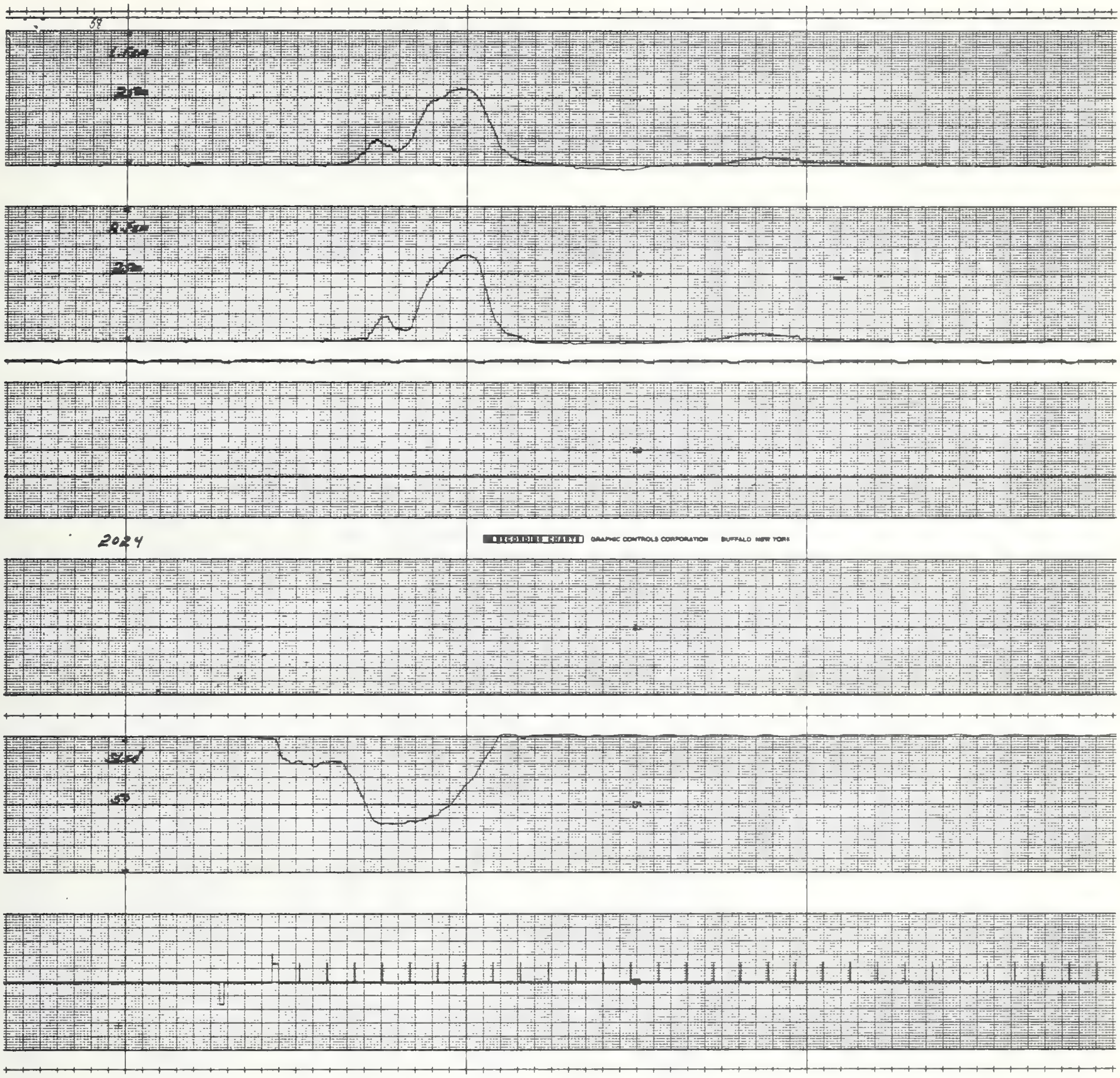
POST TEST
RUN 2024



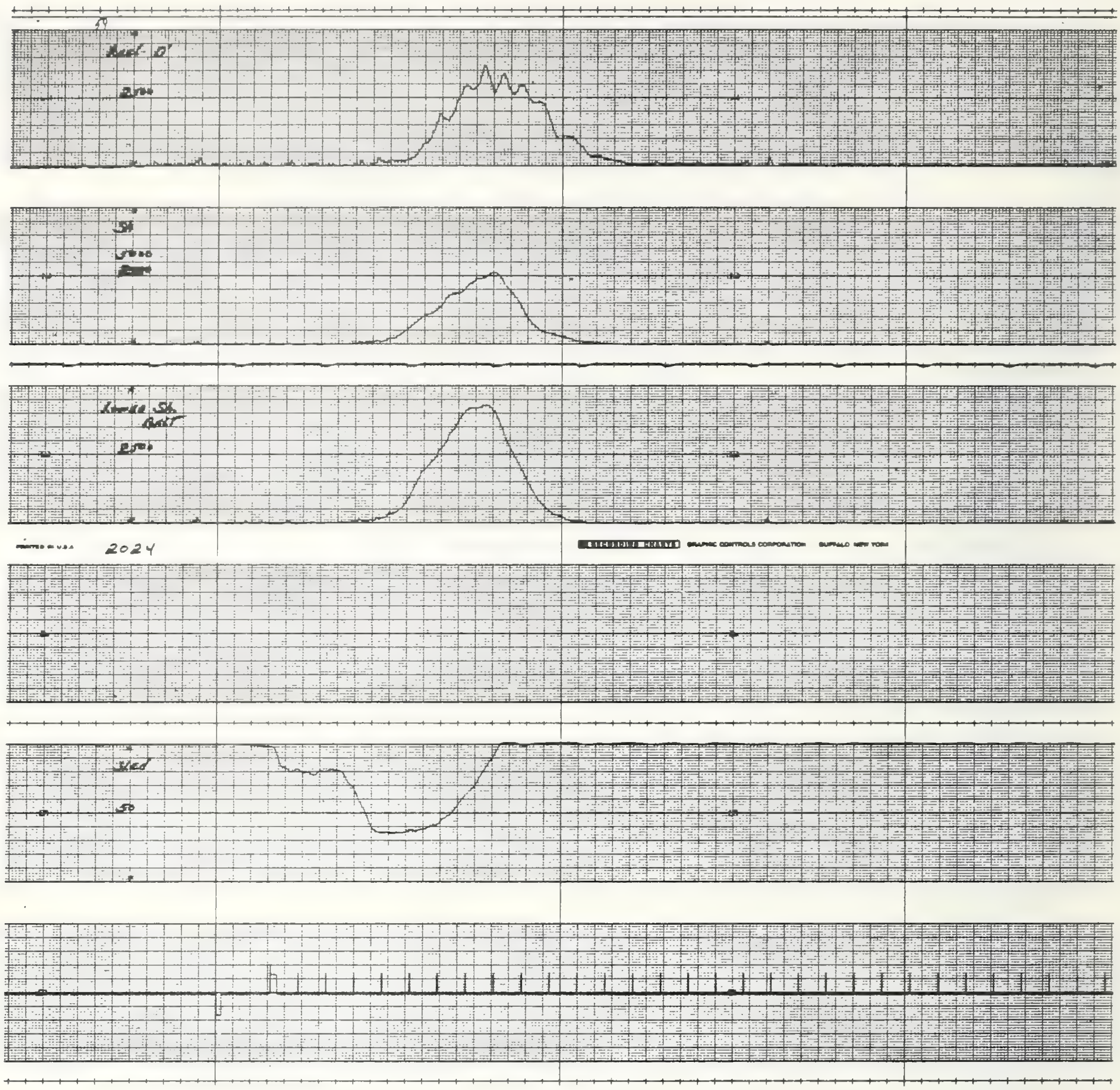
Time = 10 ms/division



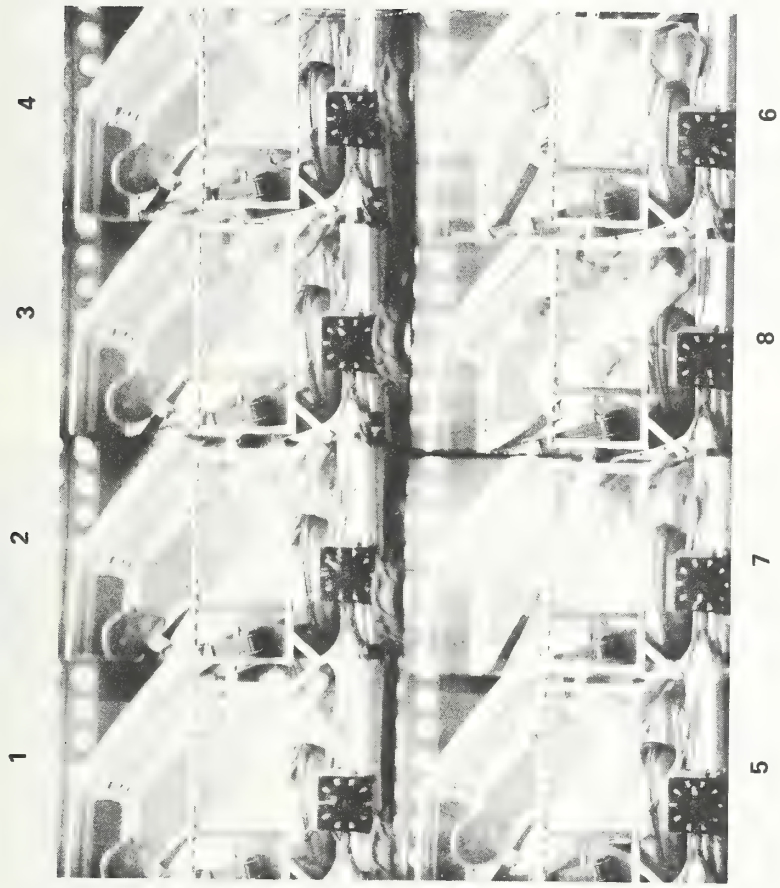
Time = 10 ms/division



Time = 10 ms/division

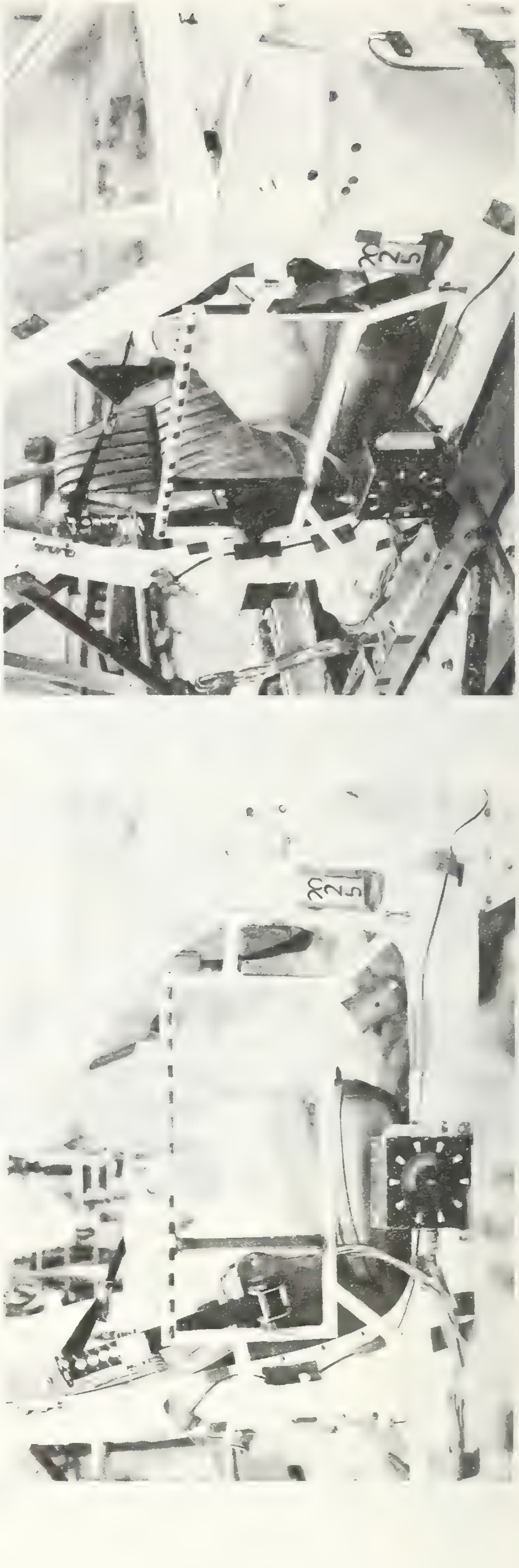


Time = 10 ms/division

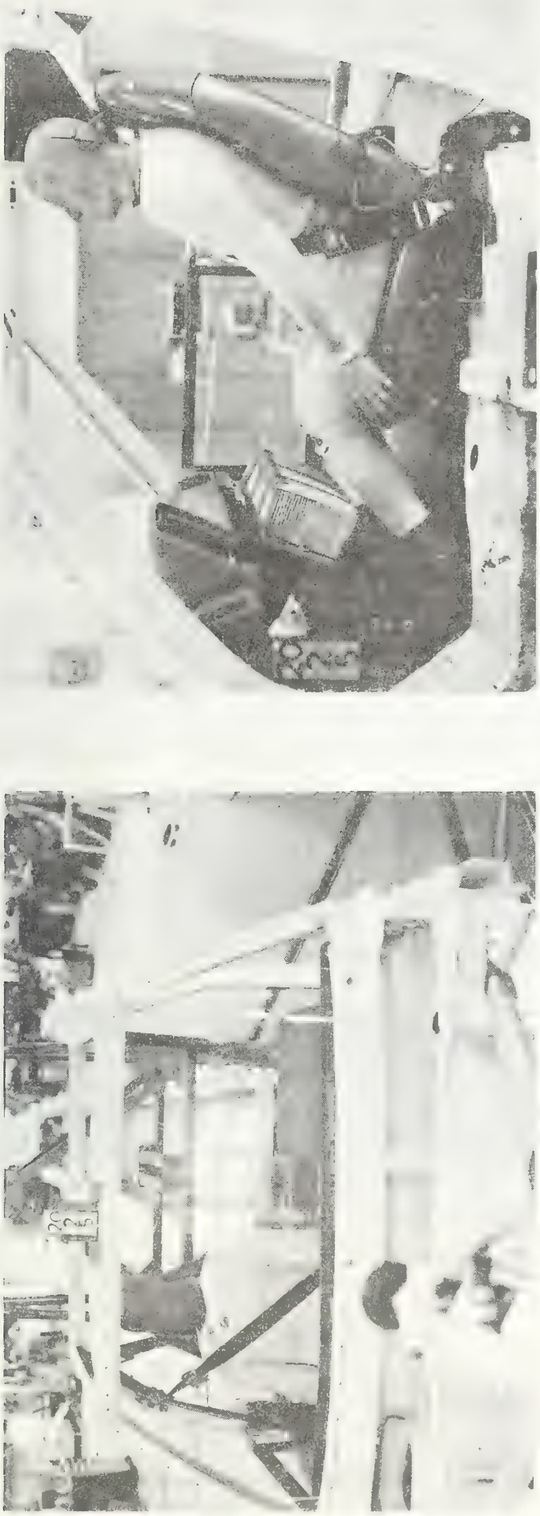


RUN 2025 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

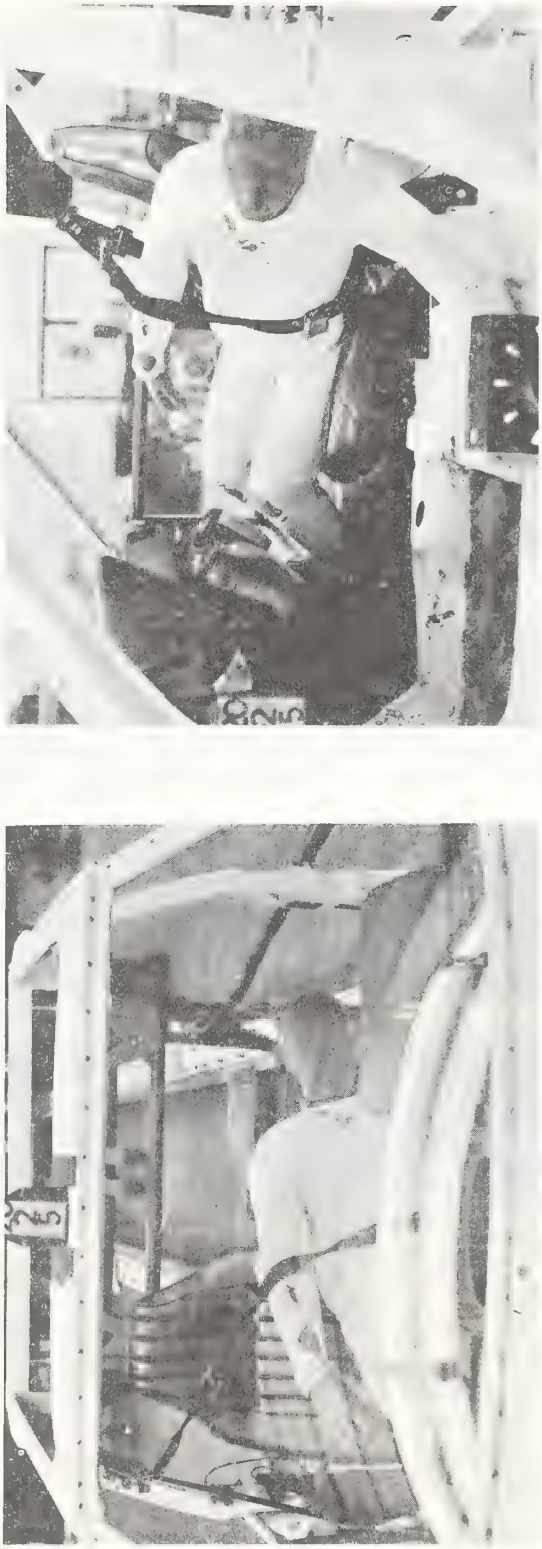
PRETEST



POST TEST
RUN2025

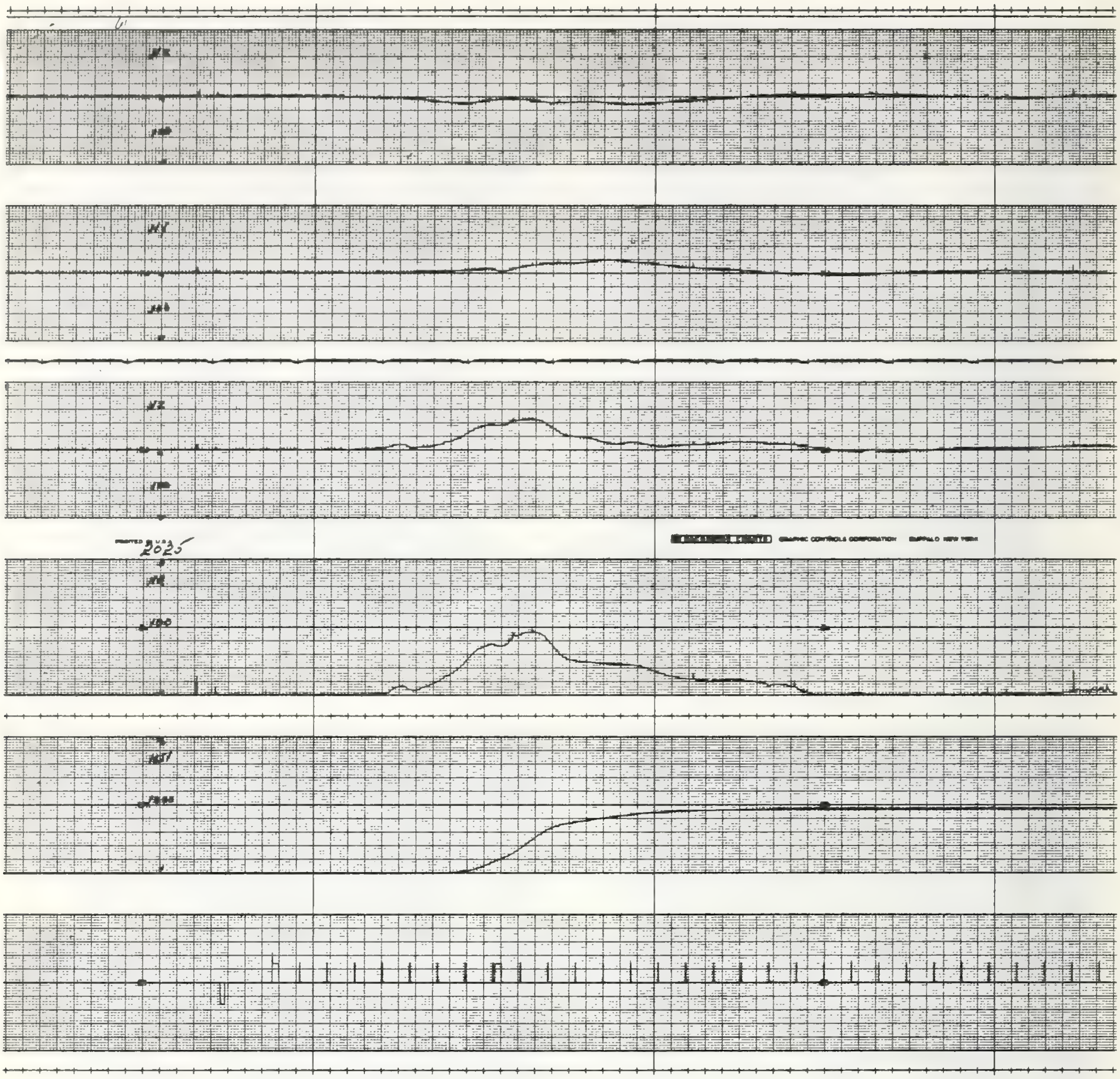


PRETEST

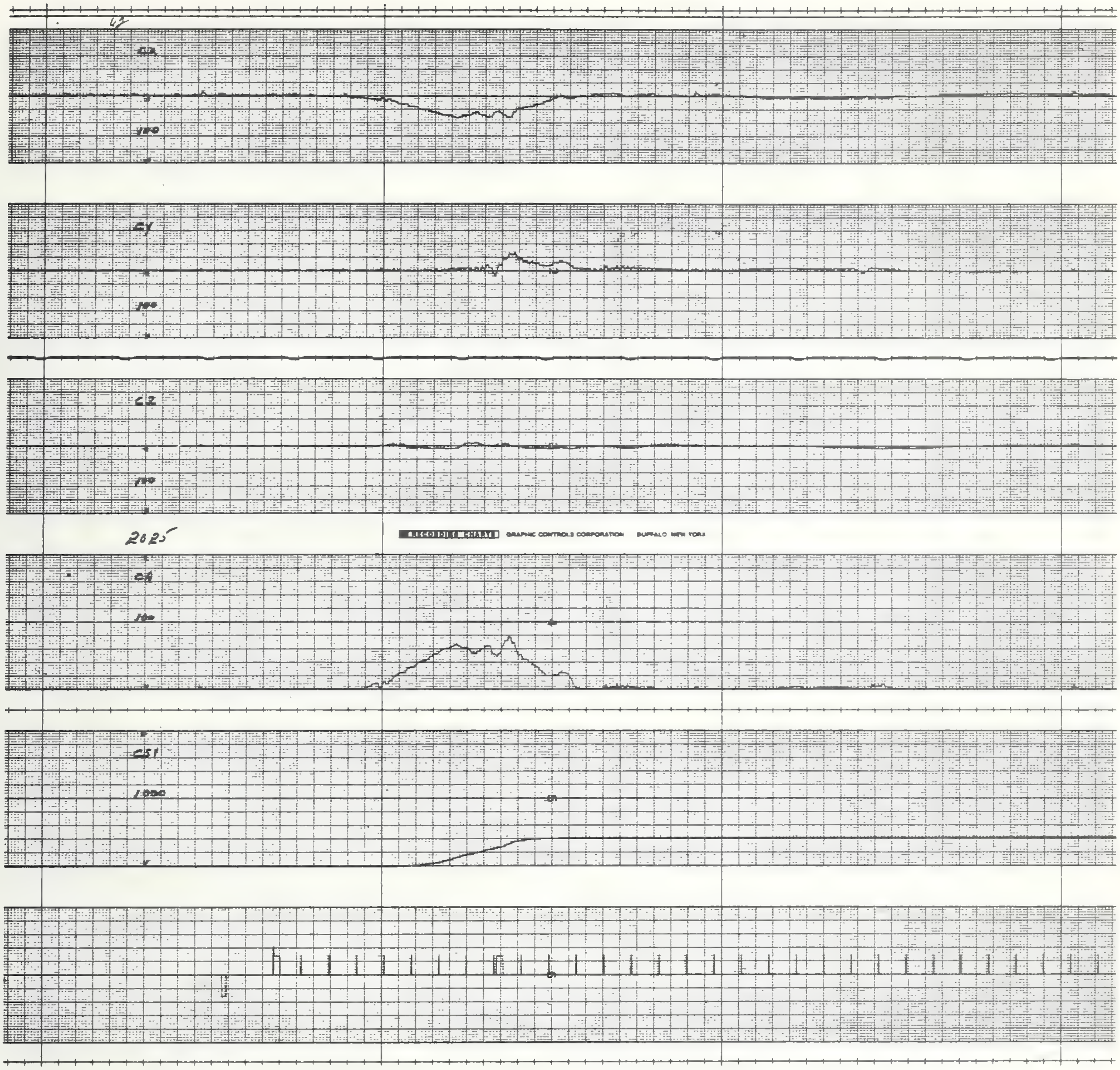


POST TEST

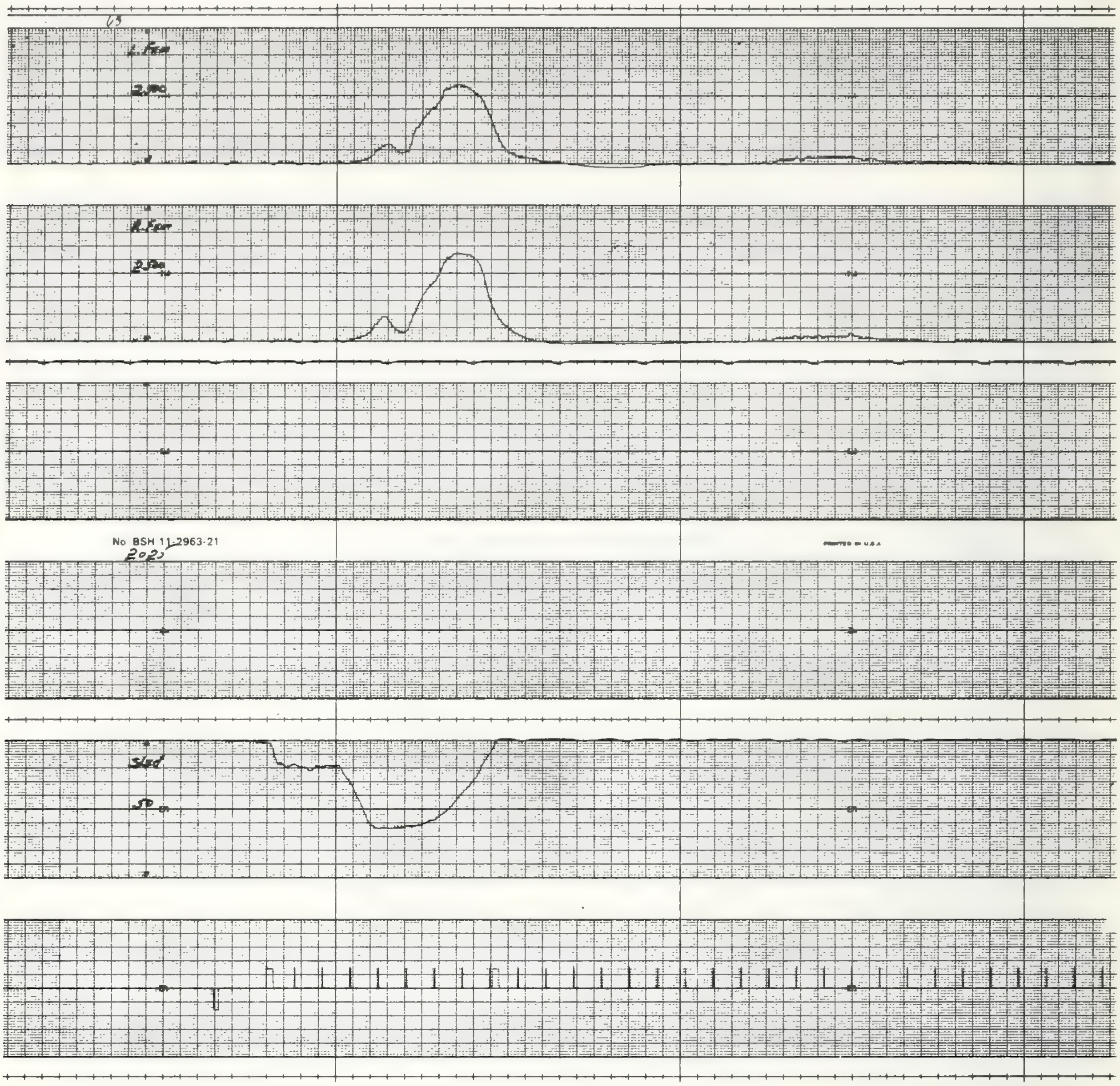
RUN 2025



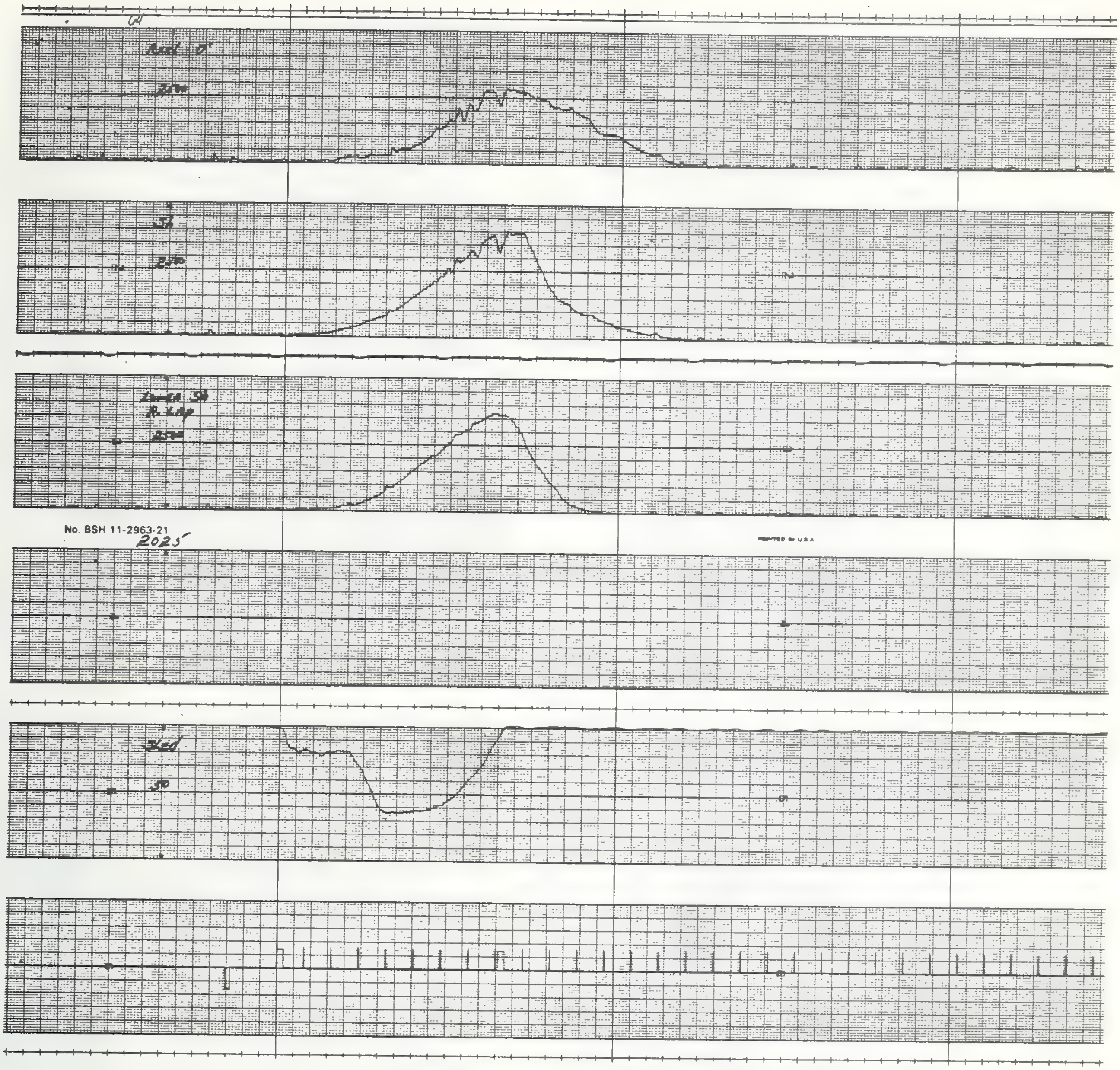
Time = 10 ms/division



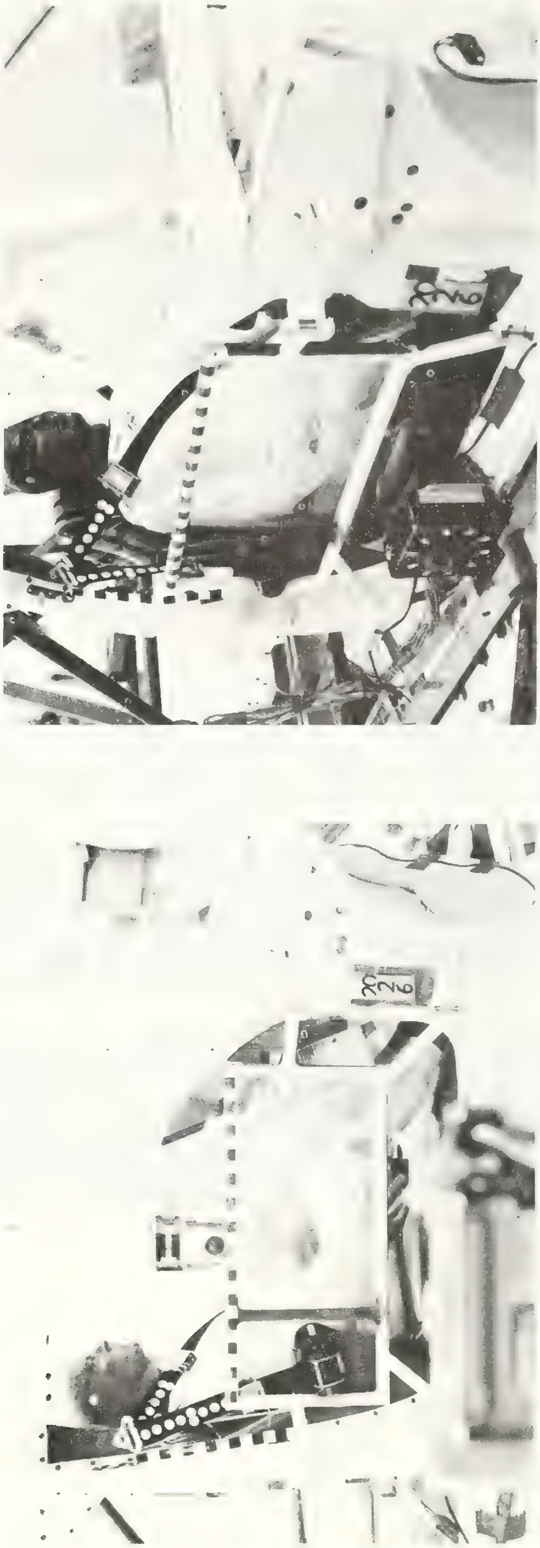
Time = 10 ms/division



Time = 10 ms/division



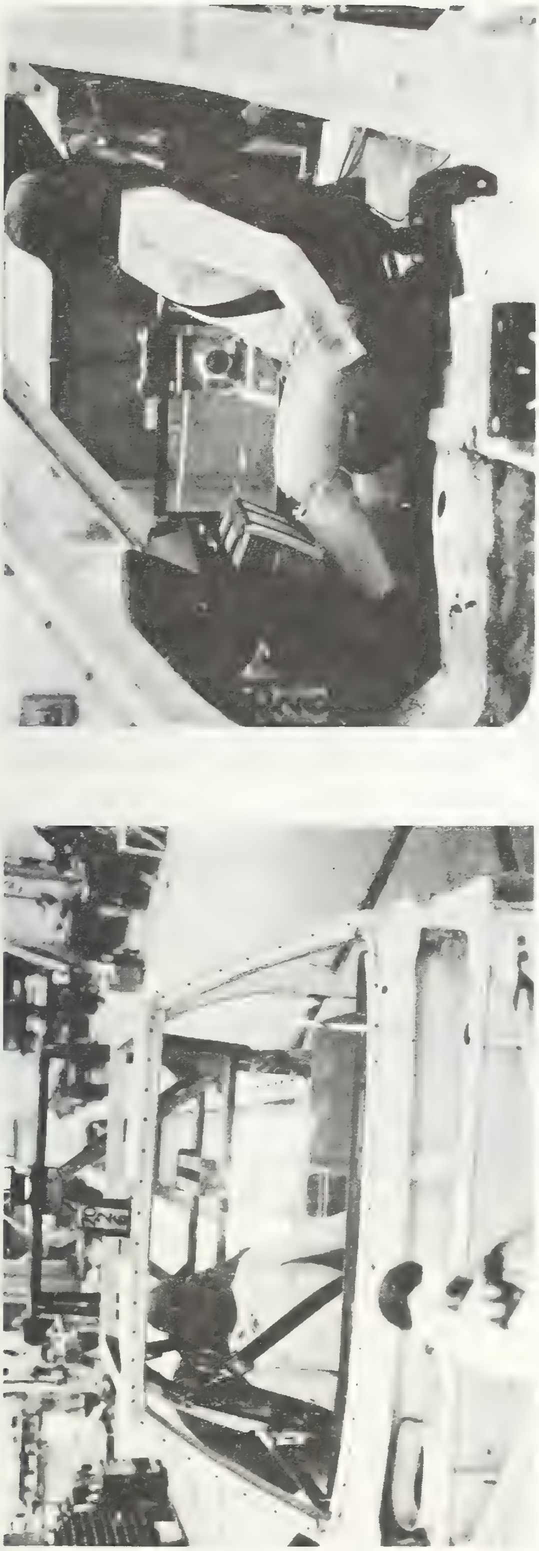
Time = 10 ms/division



PRETEST

POST TEST

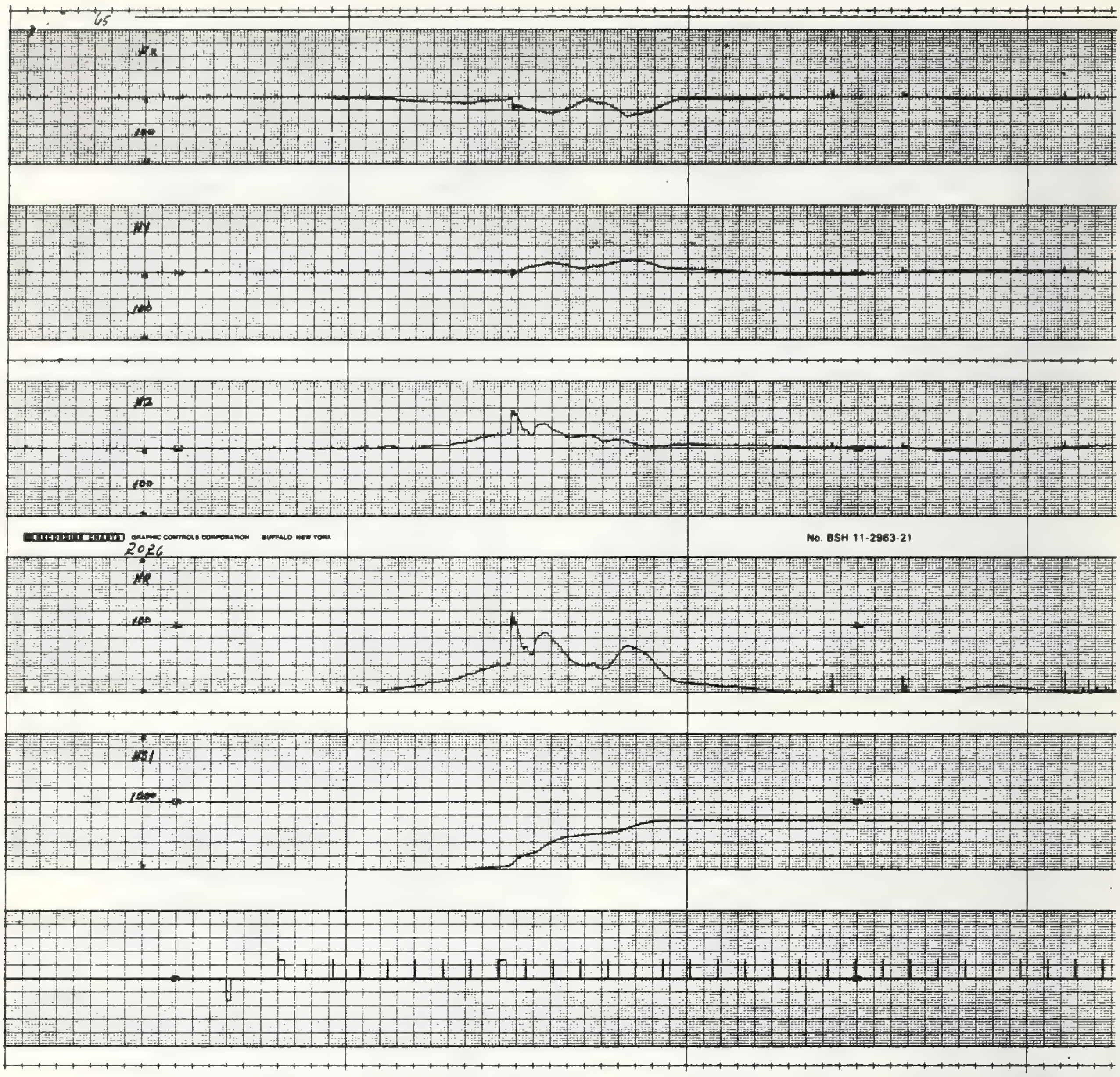
RUN 2026



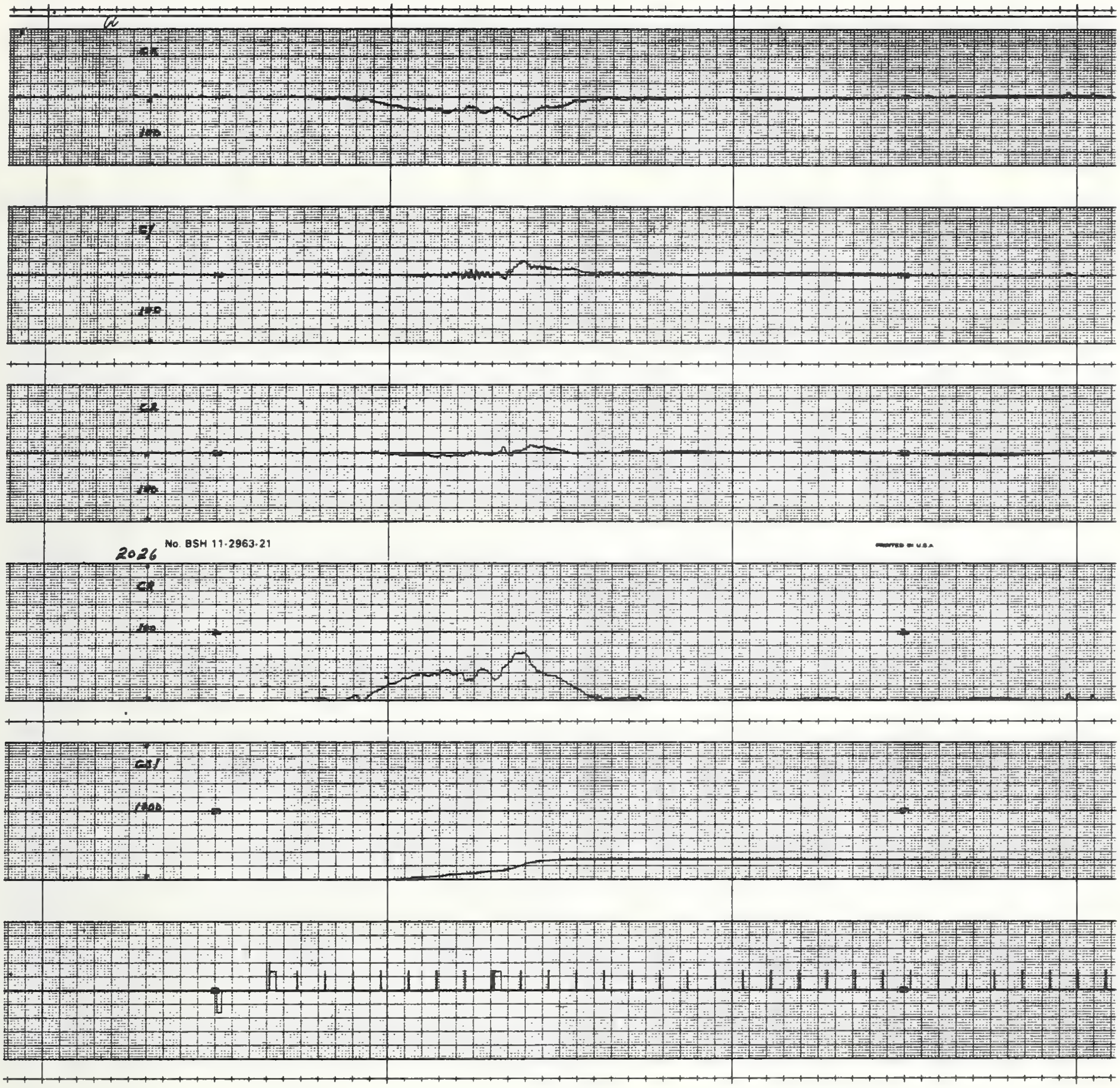
PRETEST

POST TEST

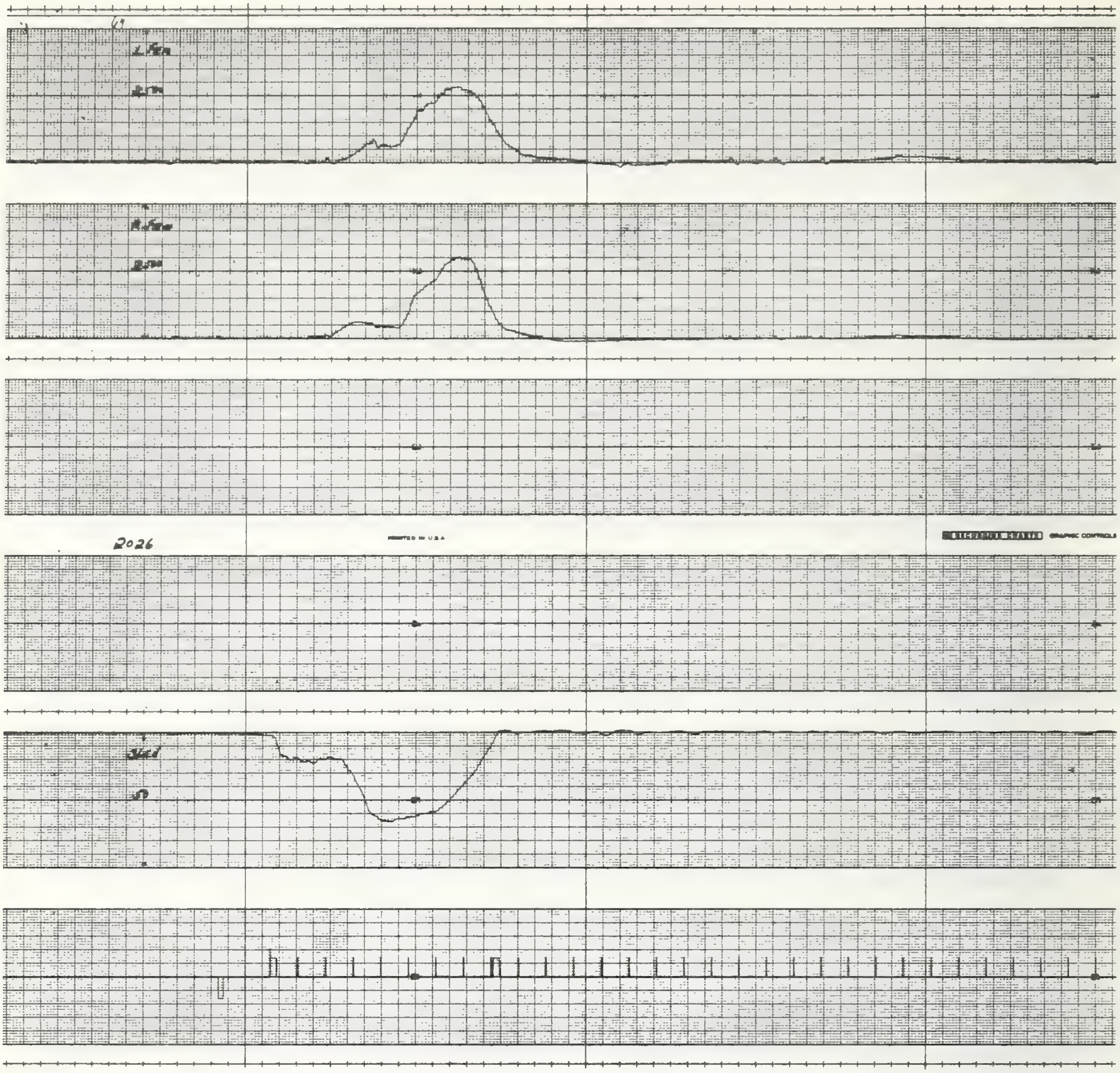
RUN 2026



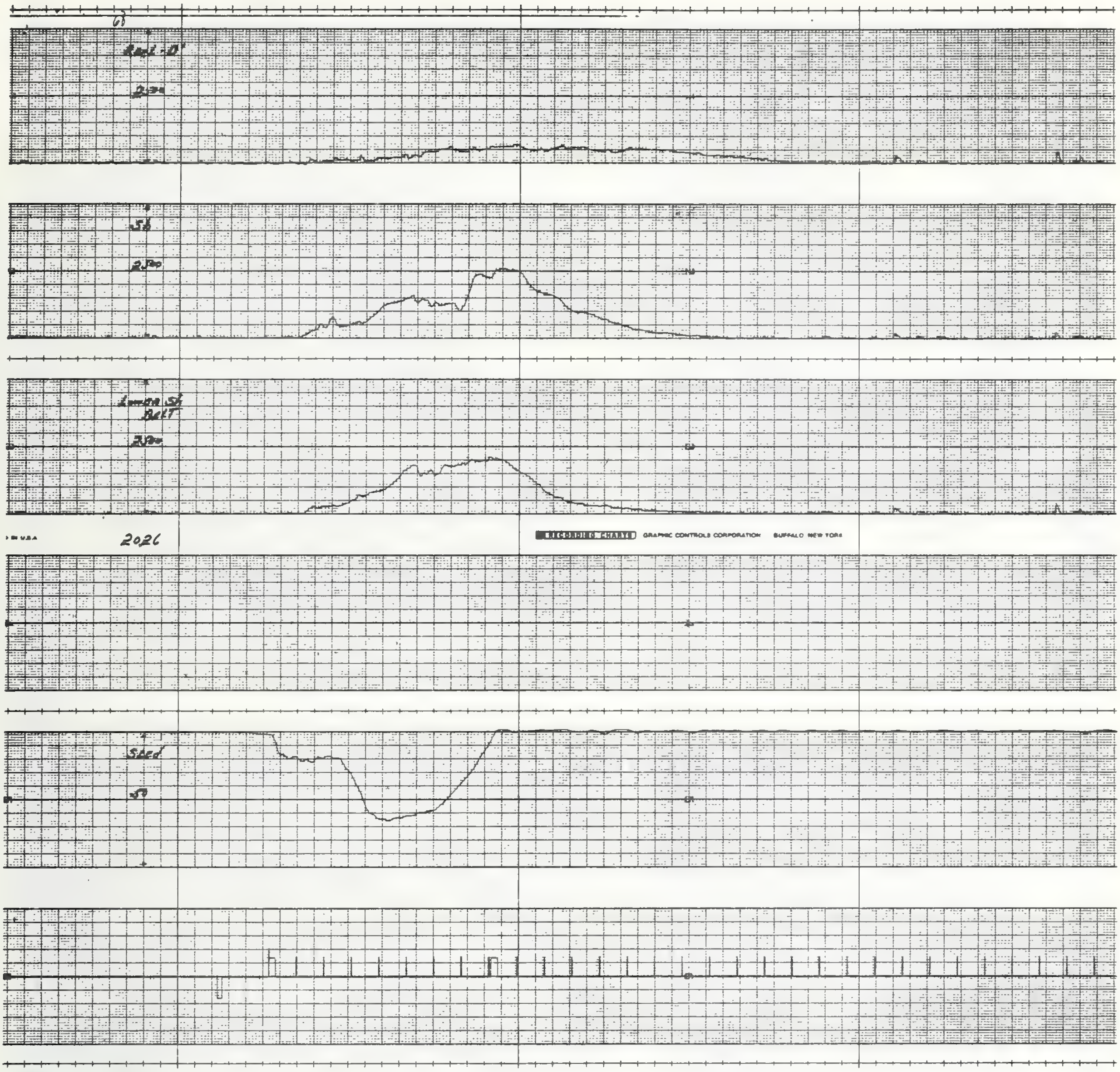
Time = 10 ms/division



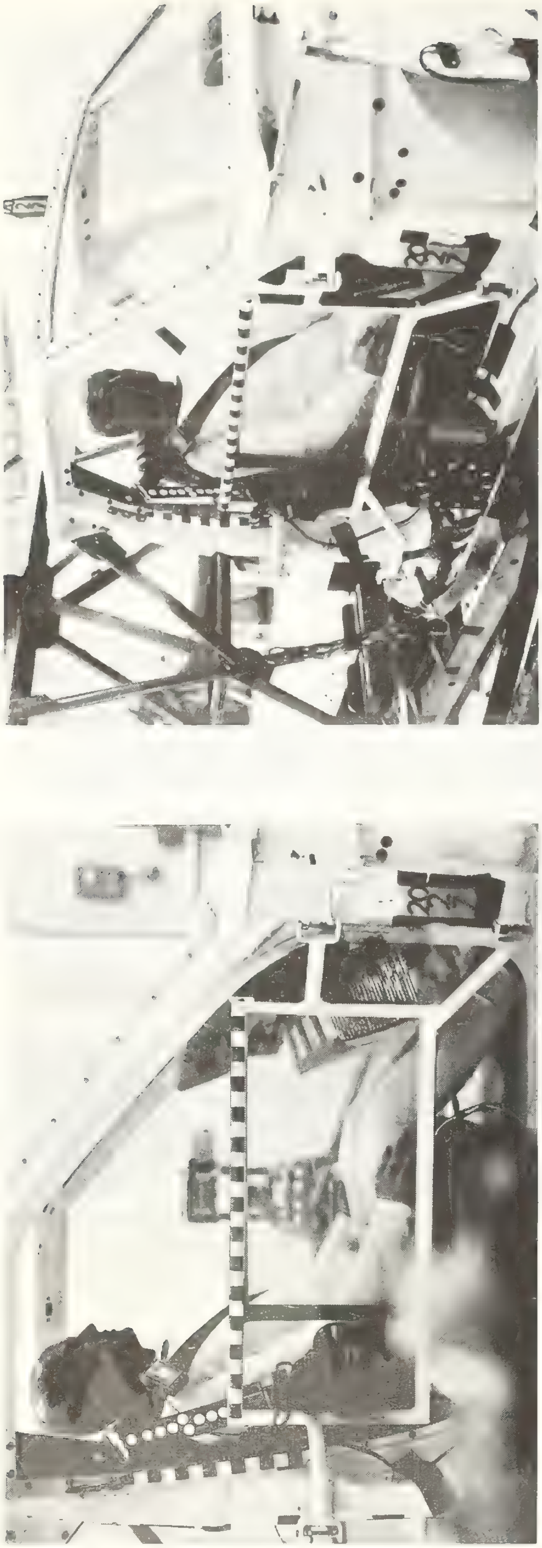
Time = 10 ms/division



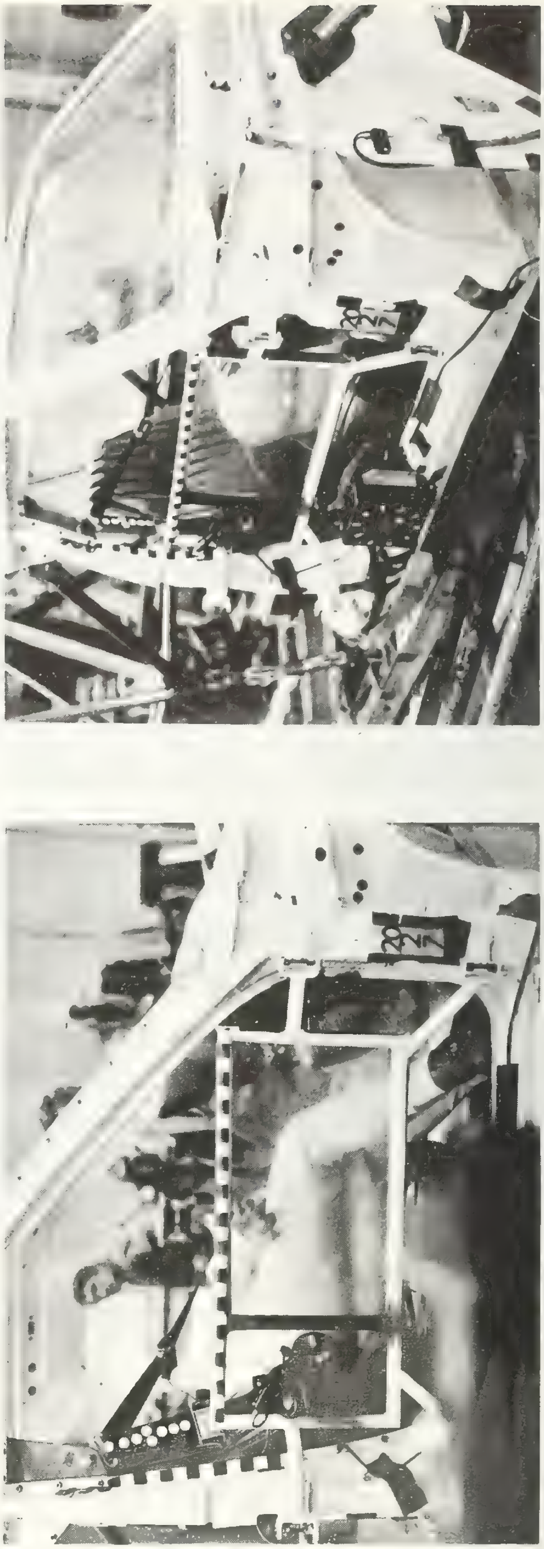
Time = 10 ms/division



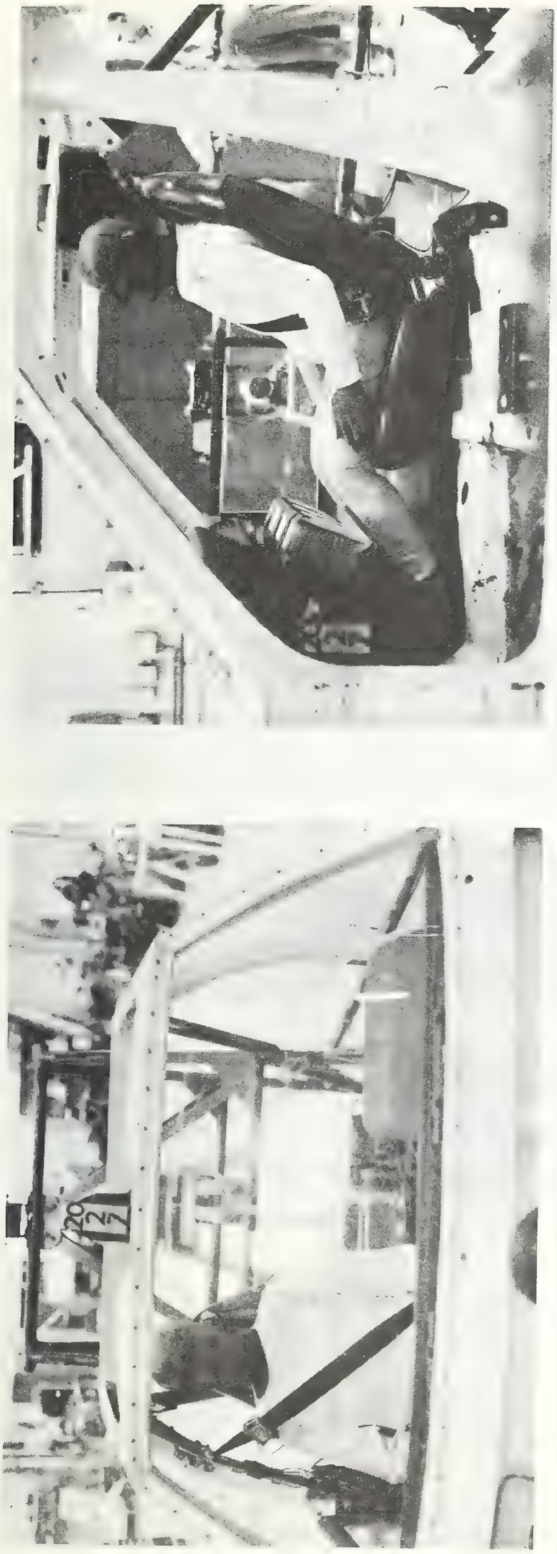
Time = 10 ms/division



PRETEST

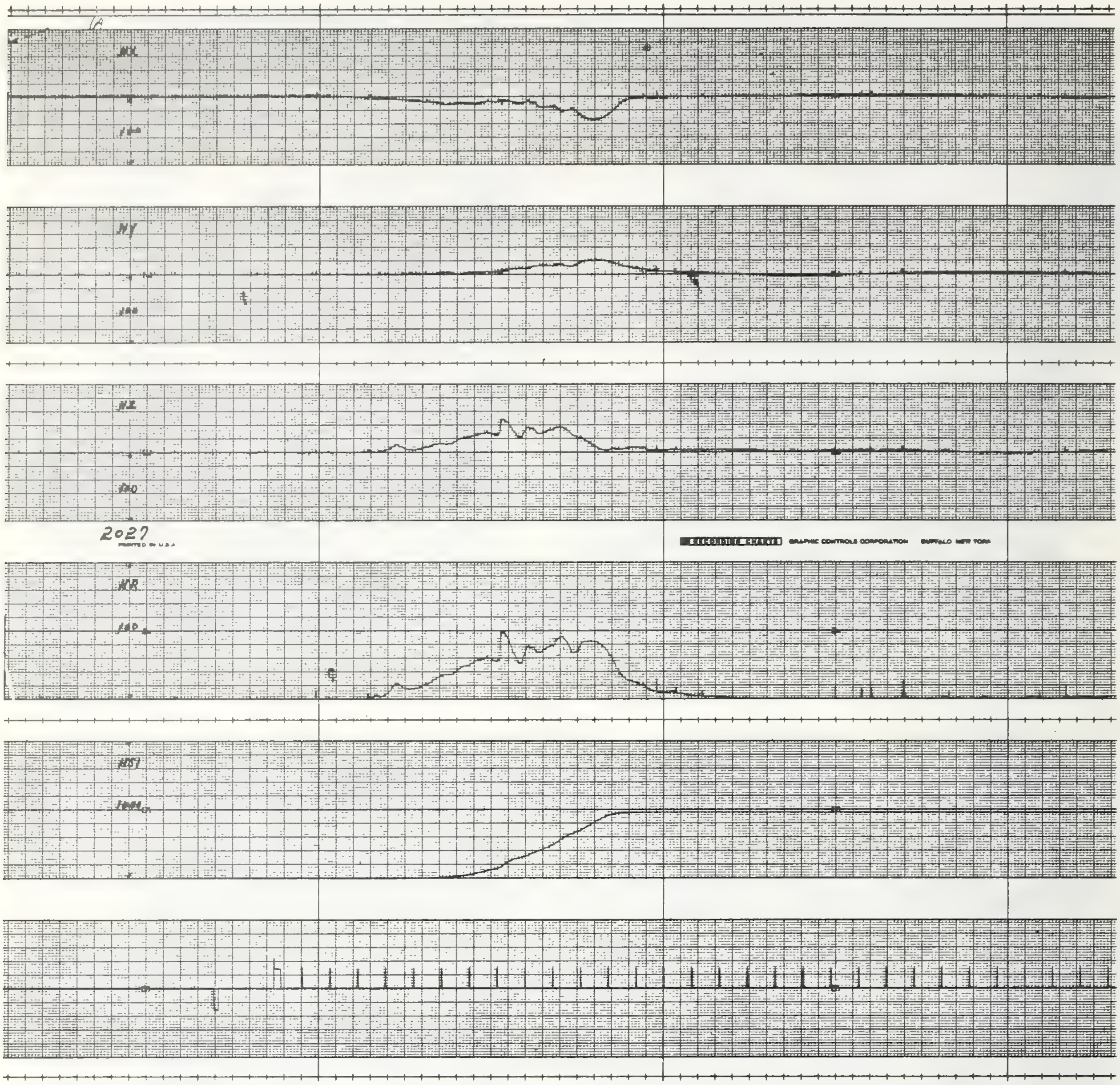


POST TEST
RUN 2027

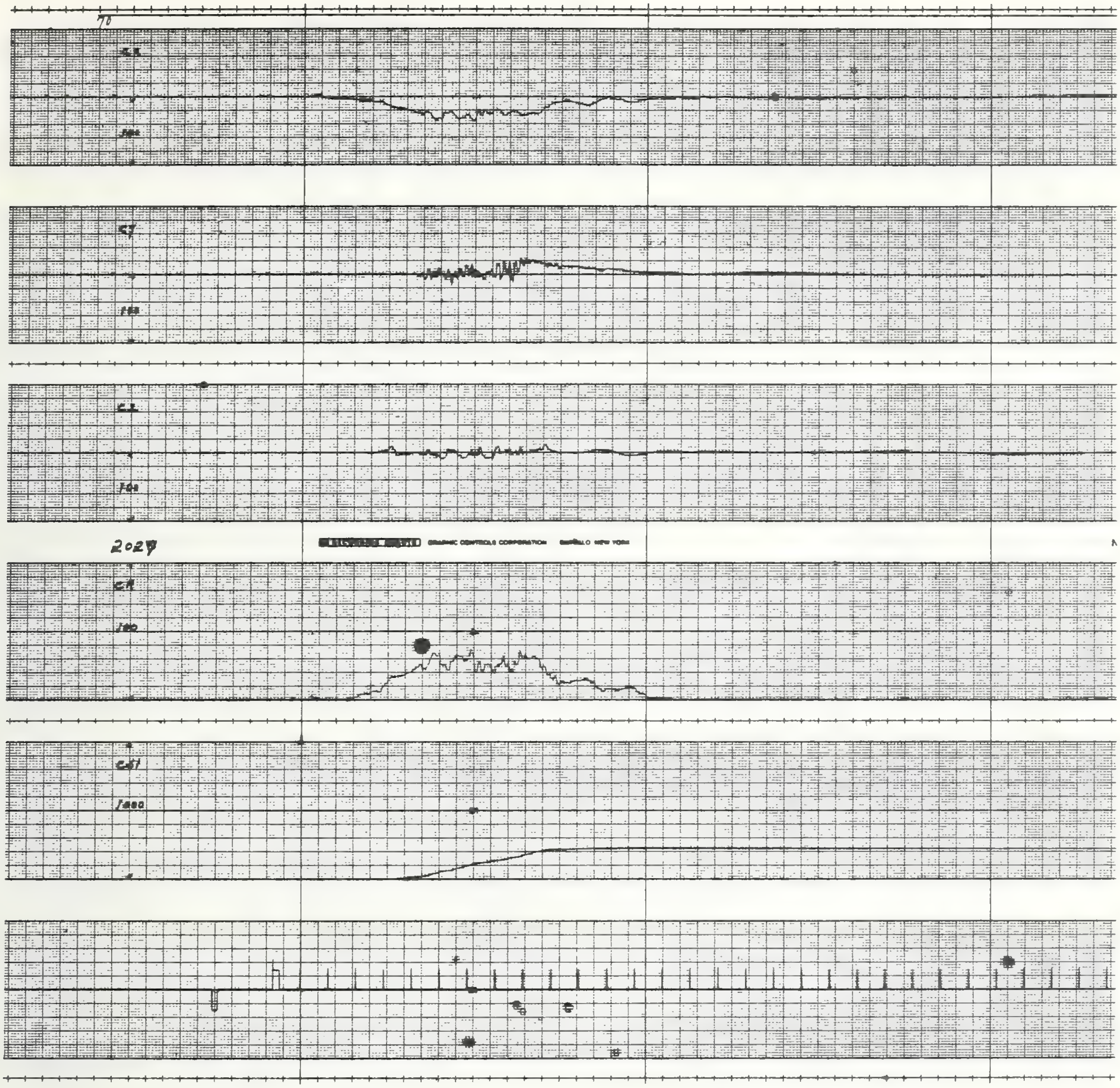


PRETEST

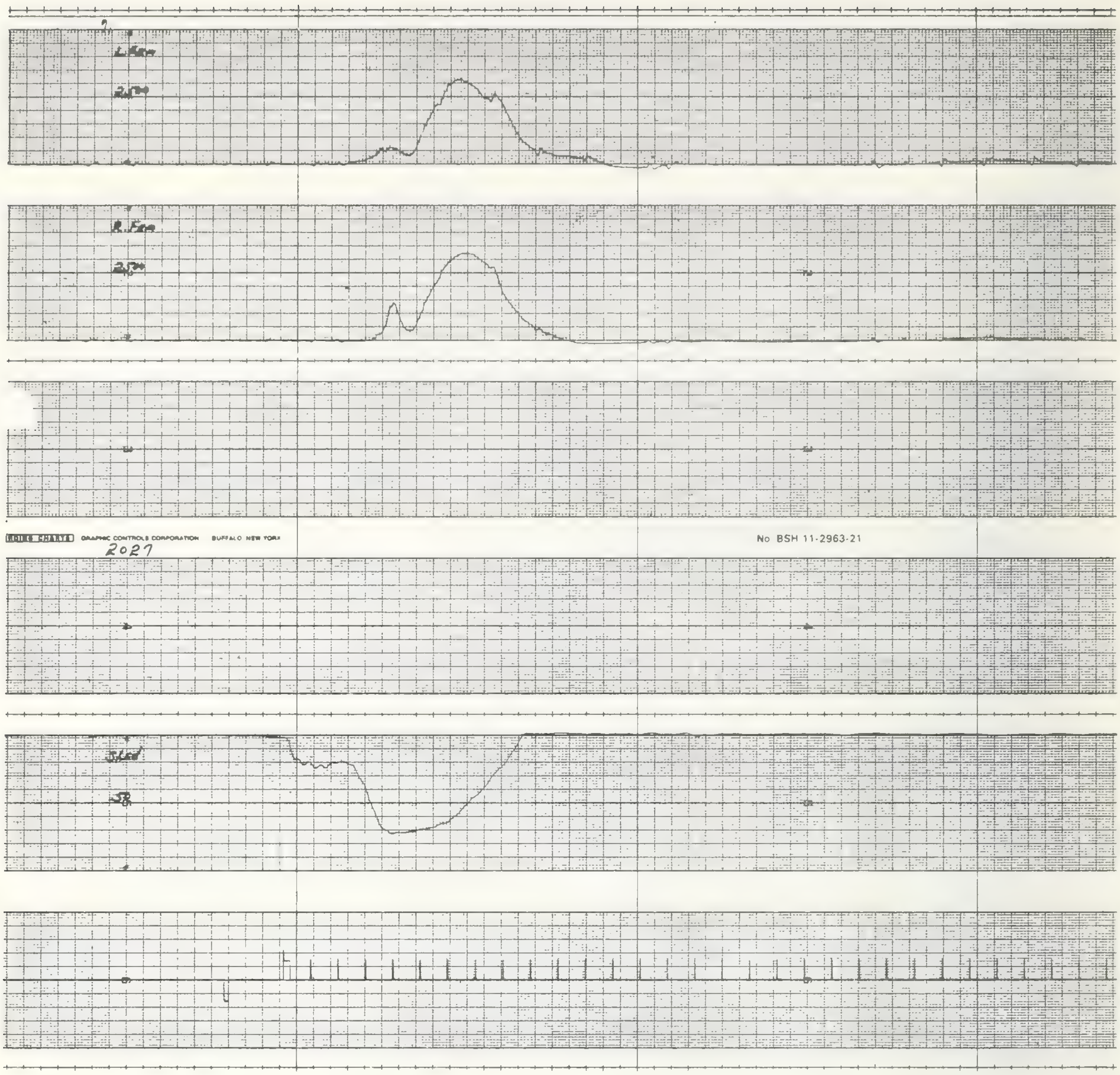
POST TEST
RUN 2027



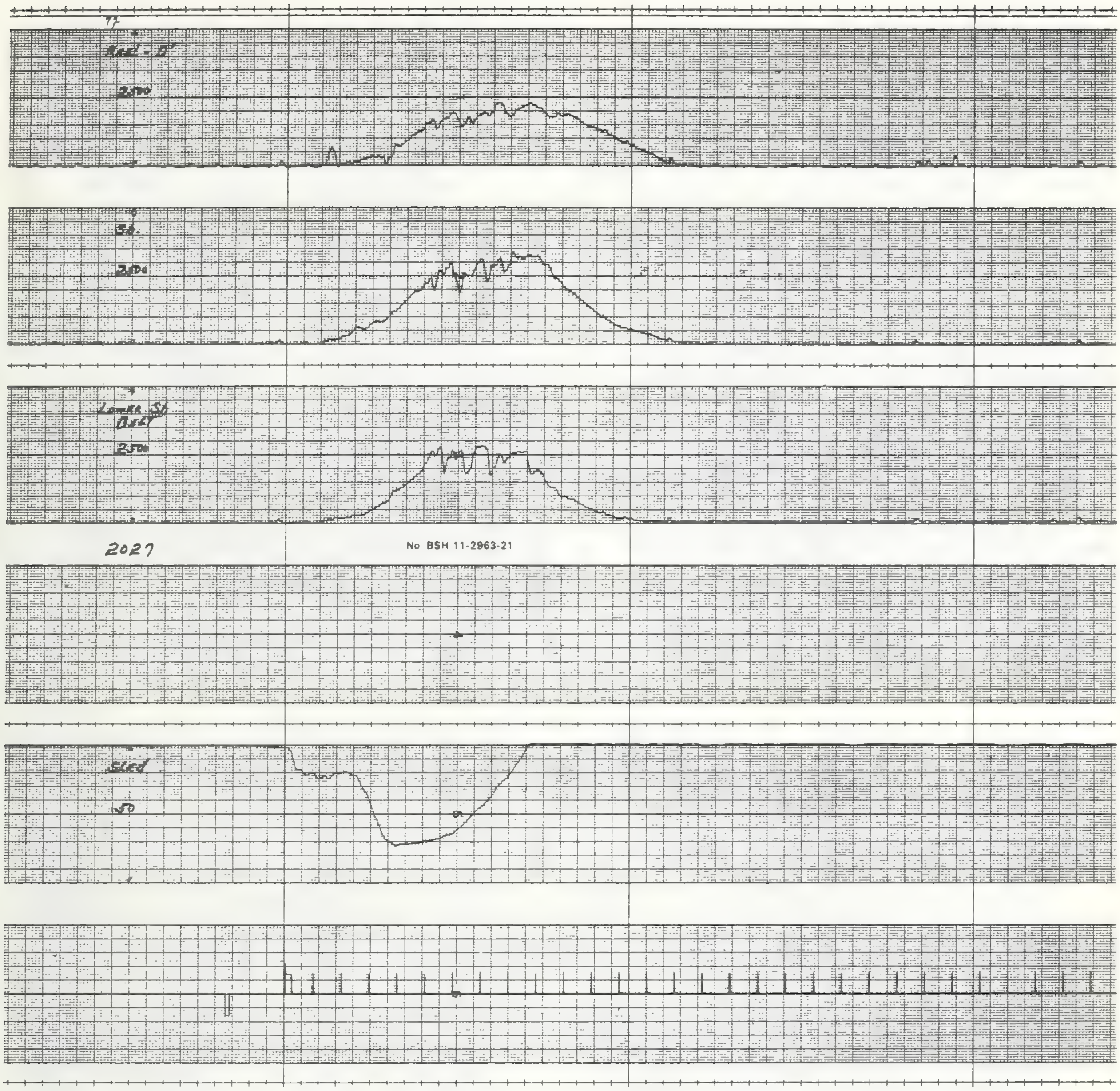
Time = 10 ms/division



Time = 10 ms/division

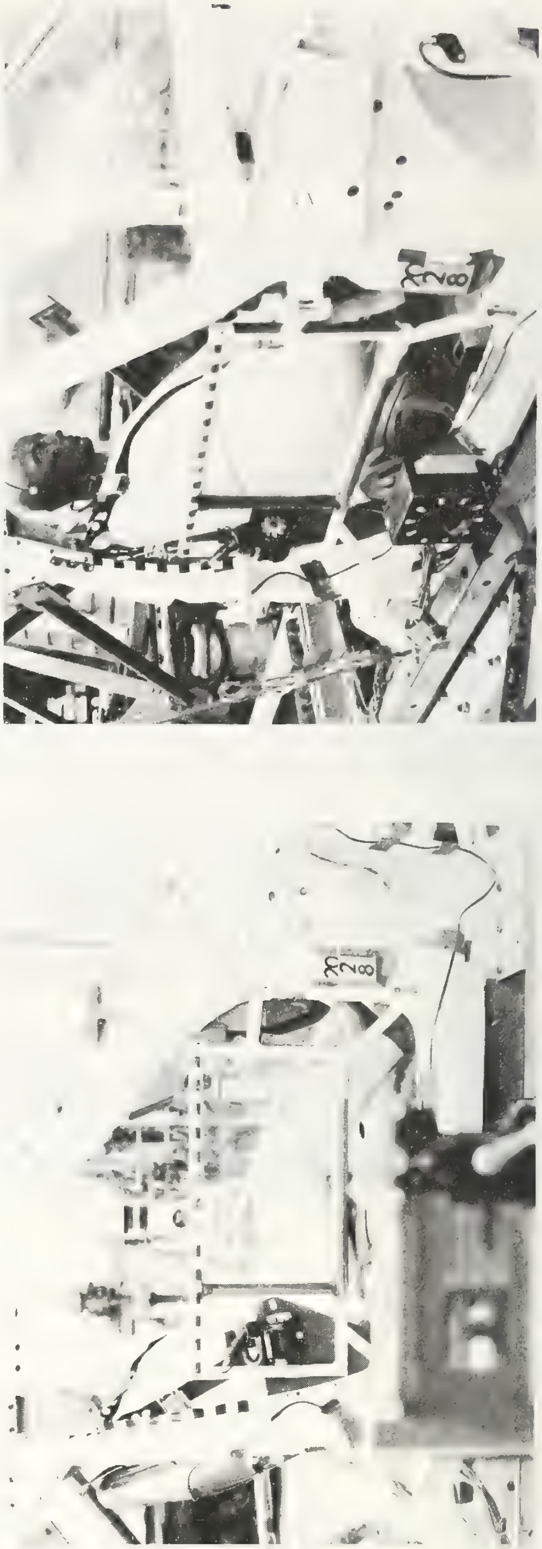


Time = 10 ms/division

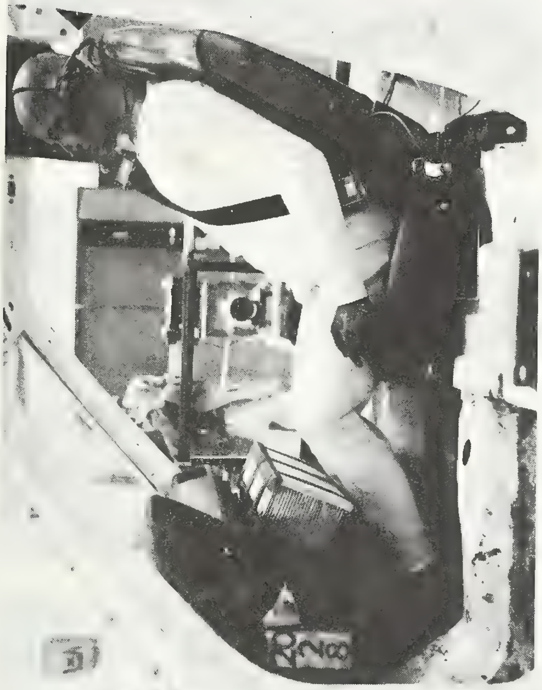


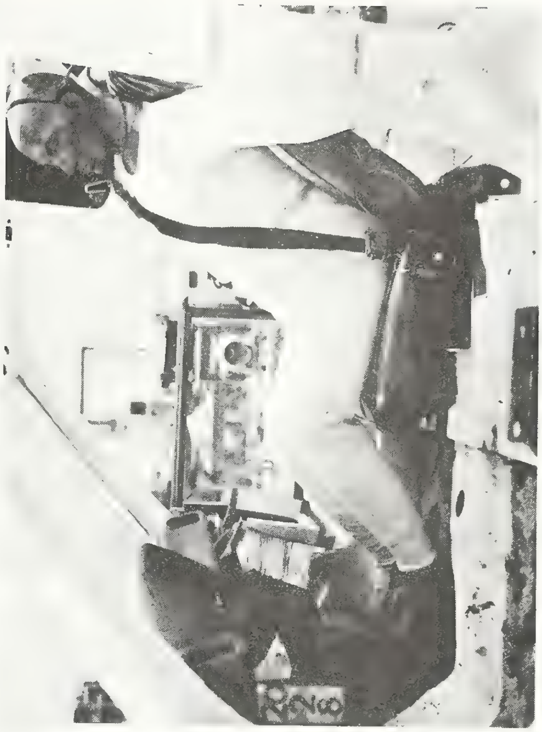
Time = 10 ms/division

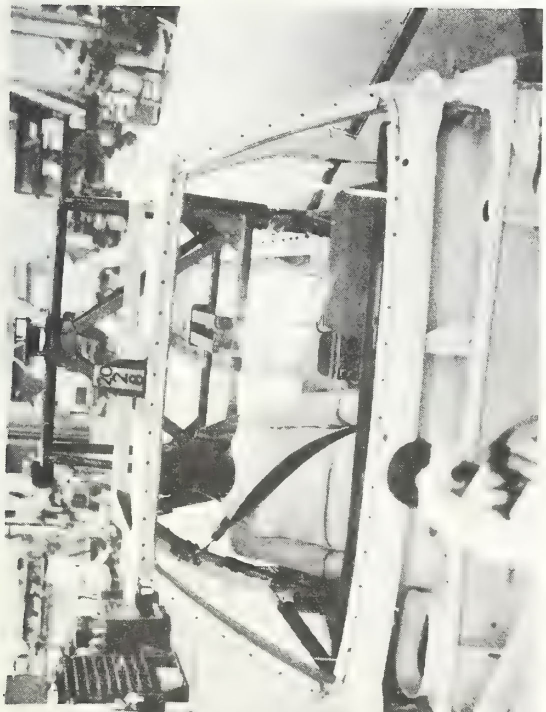
PRETEST



POST TEST
RUN 2028

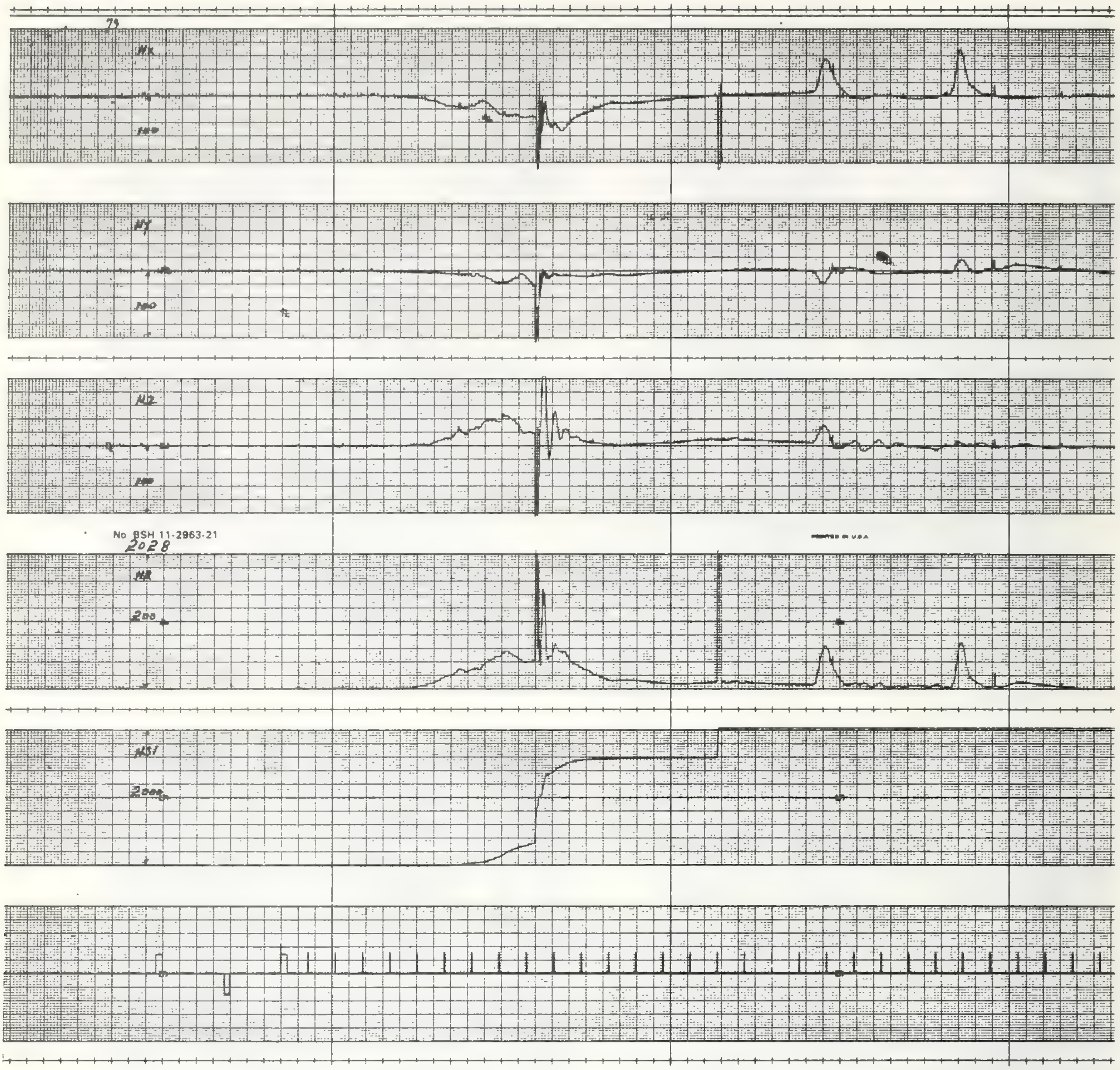




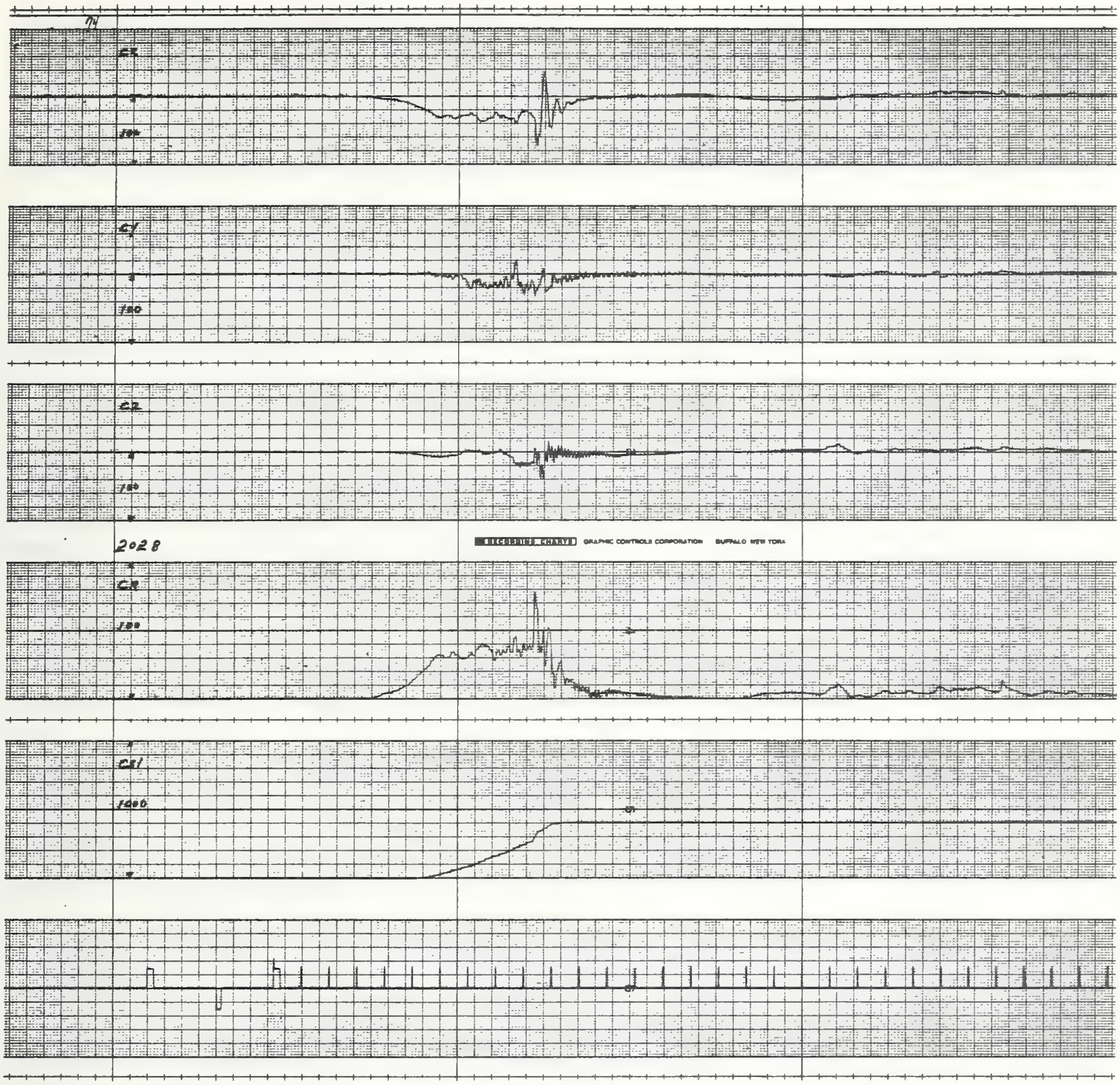


PRETEST

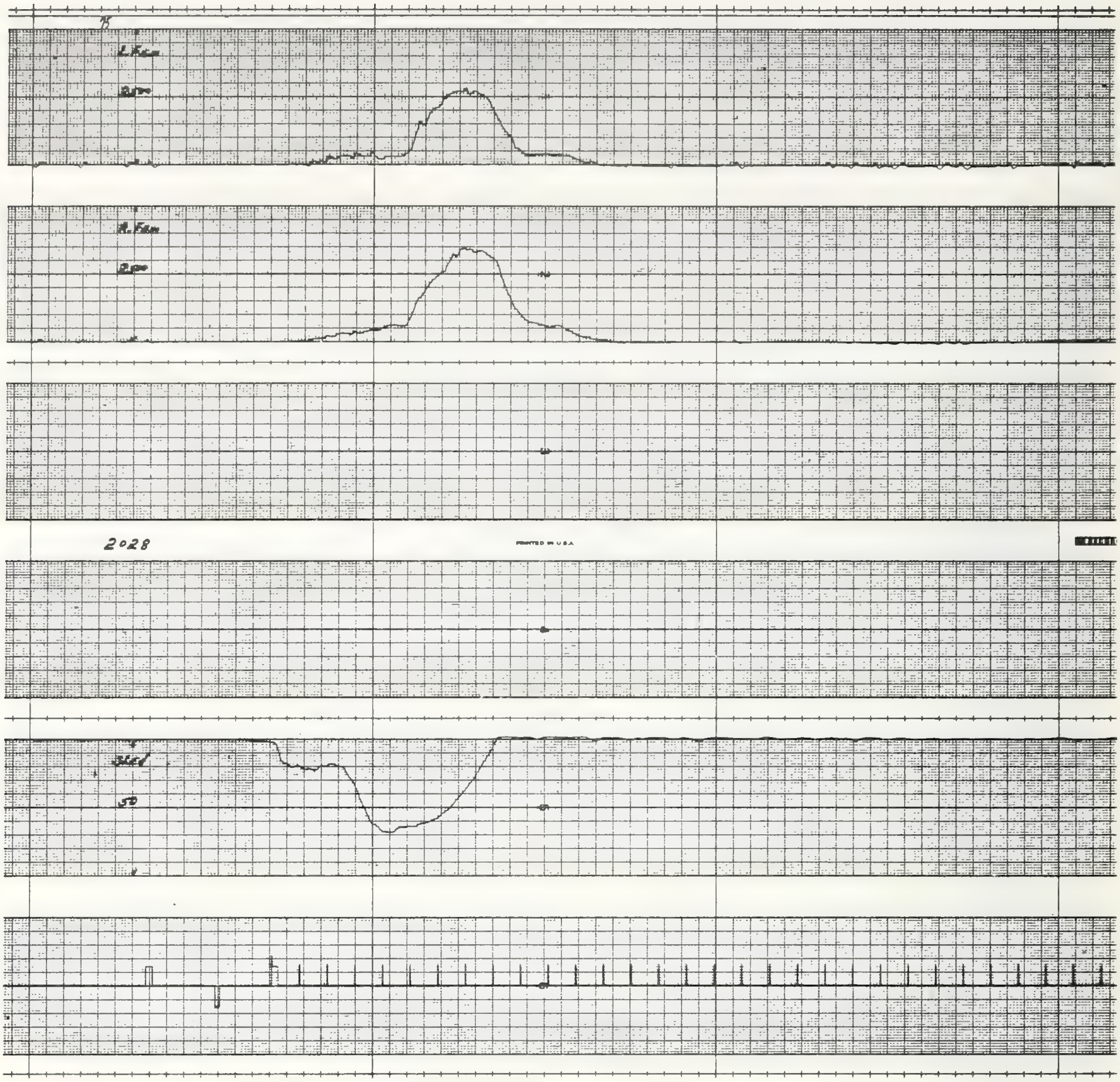
POST TEST
RUN 2028



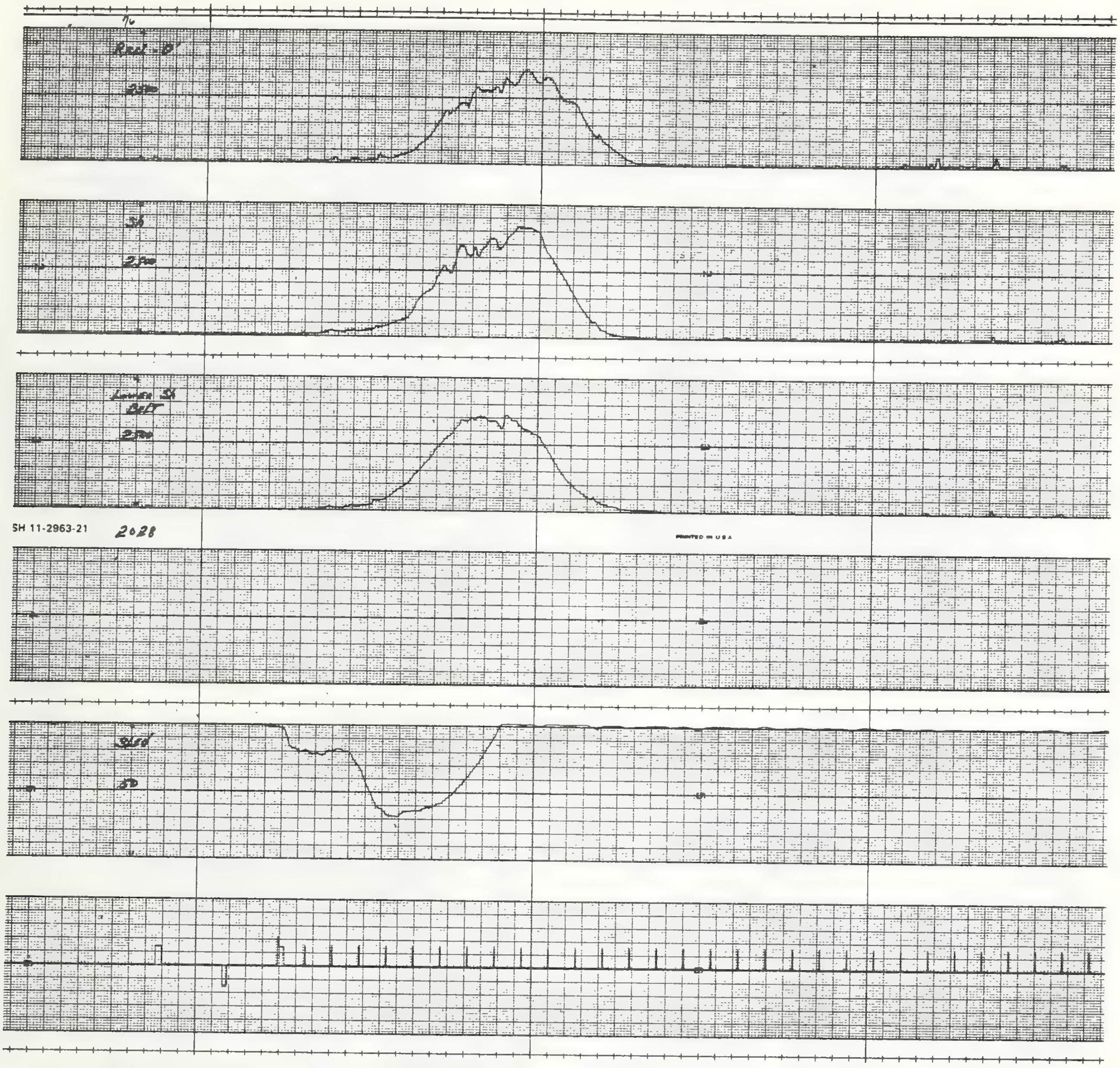
Time = 10 ms/division



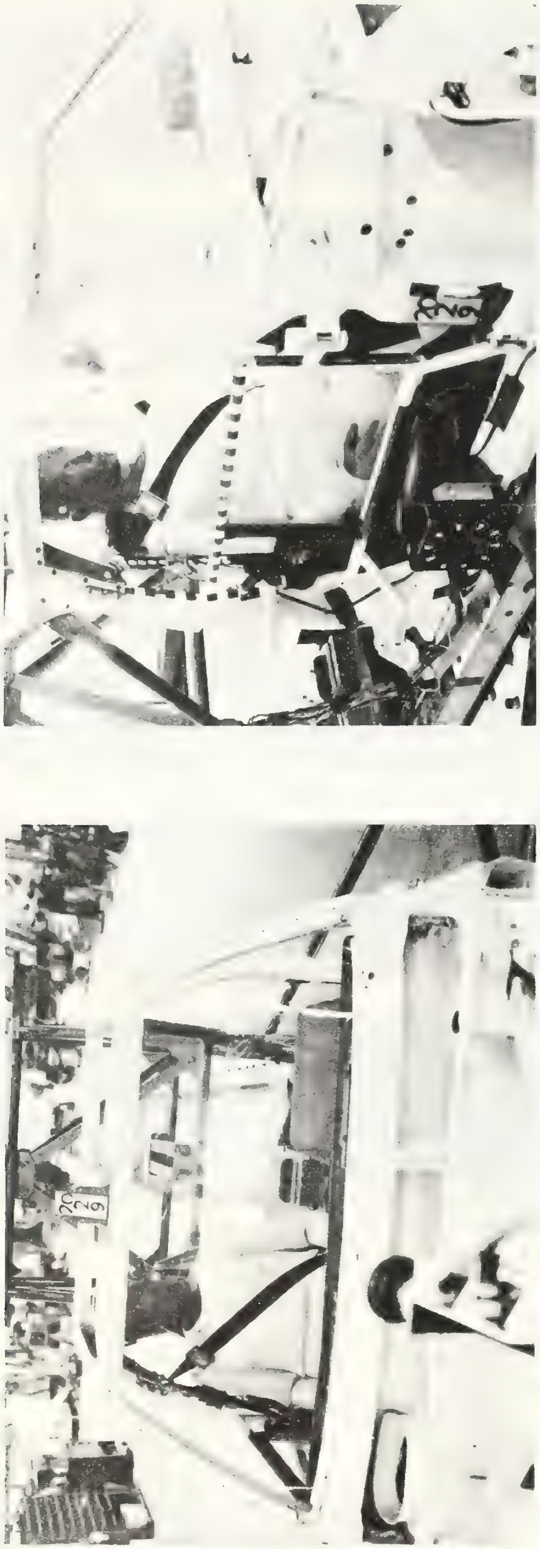
Time = 10 ms/division



Time = 10 ms/division



Time = 10 ms/division

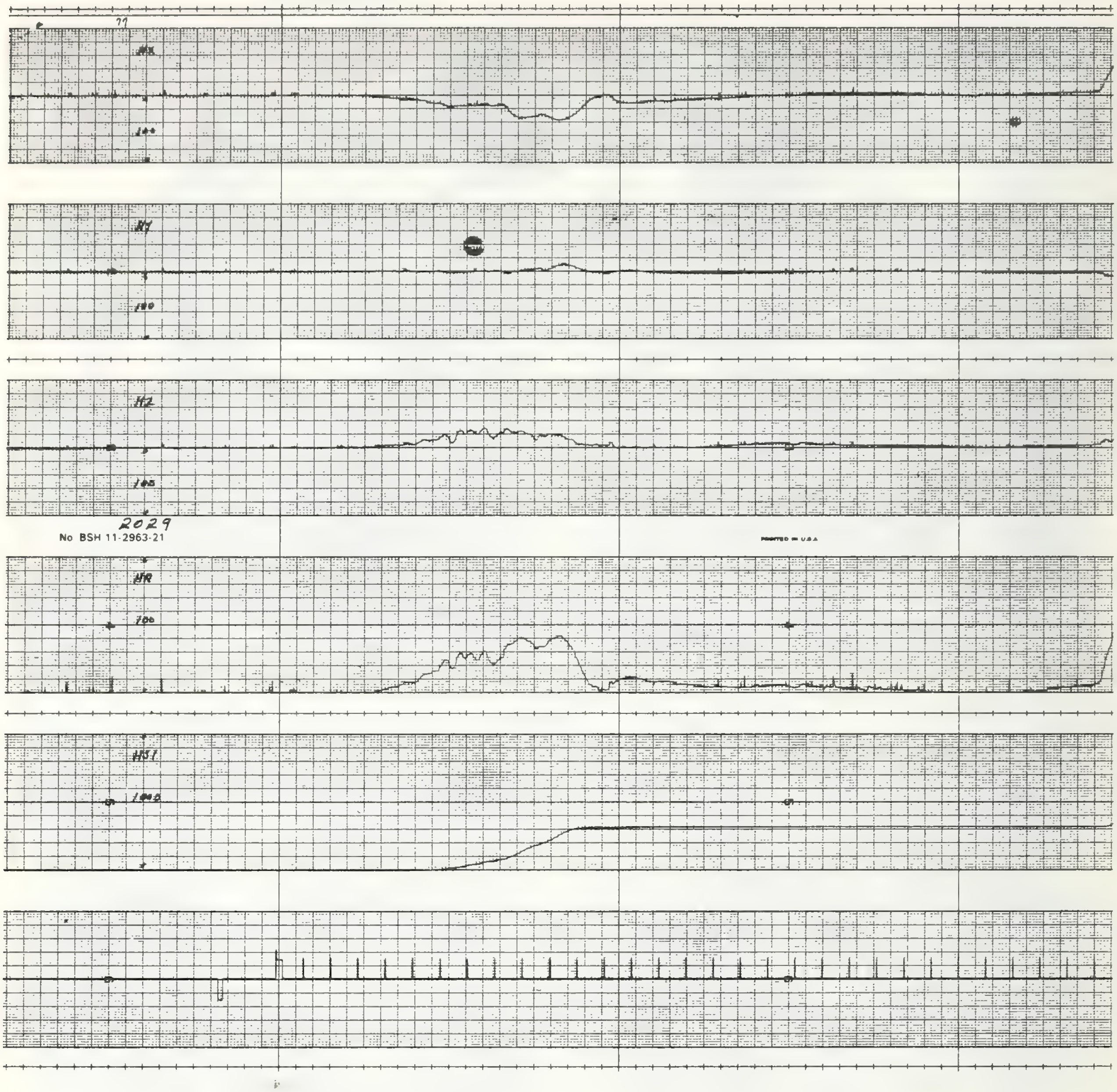


PRETEST

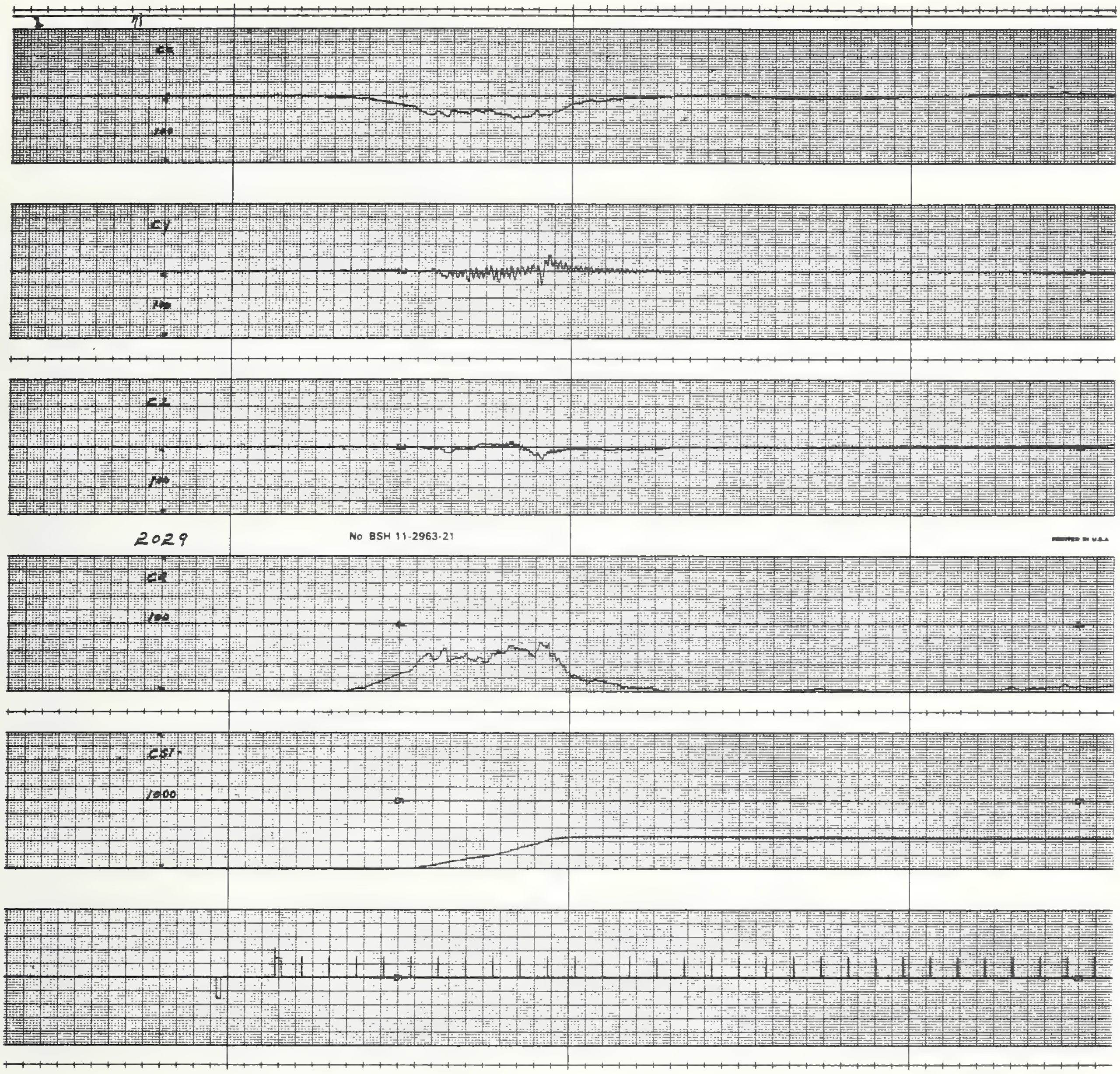
POST TEST
RUN 2029

PRETEST

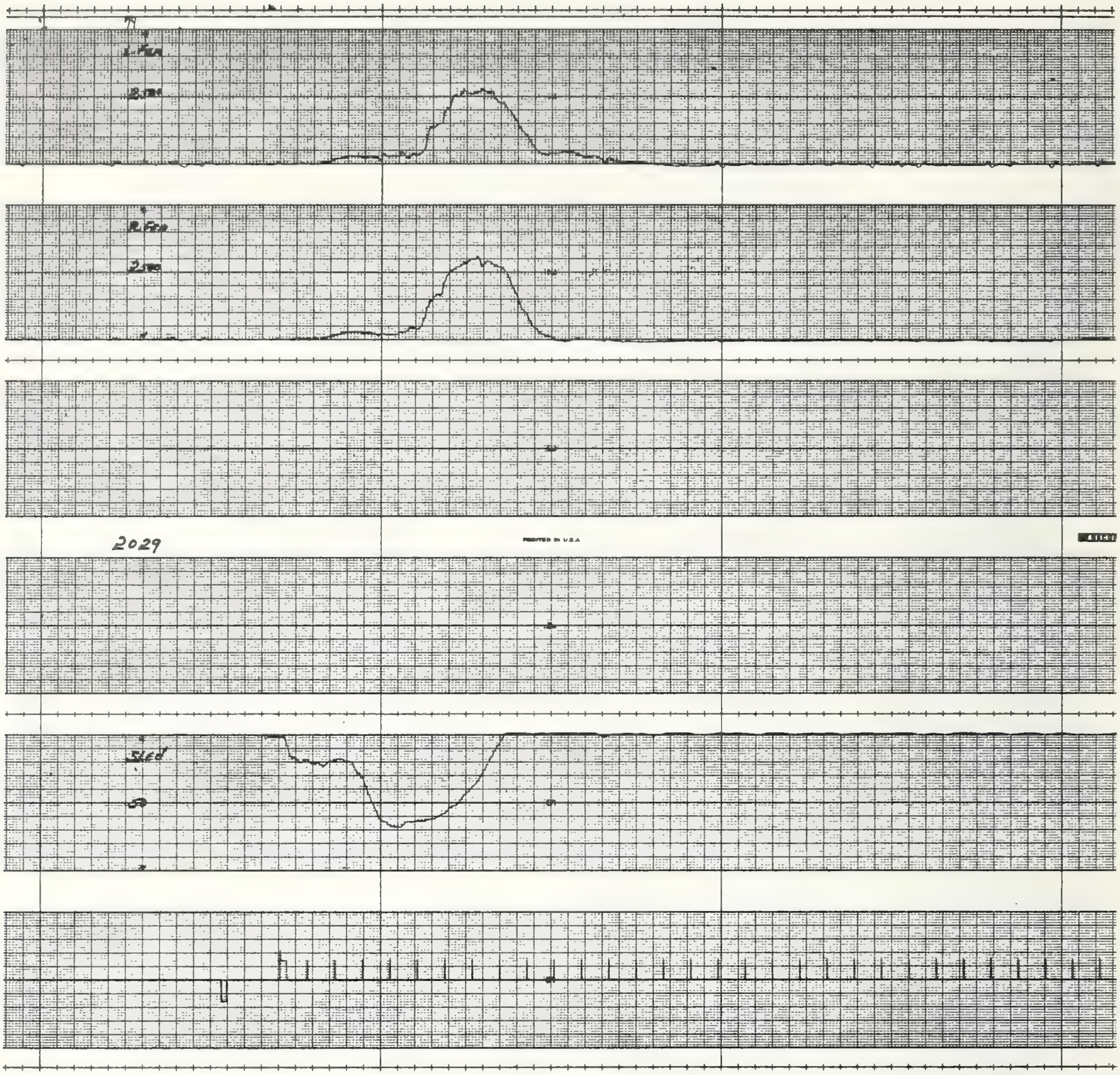
POST TEST
RUN 2029



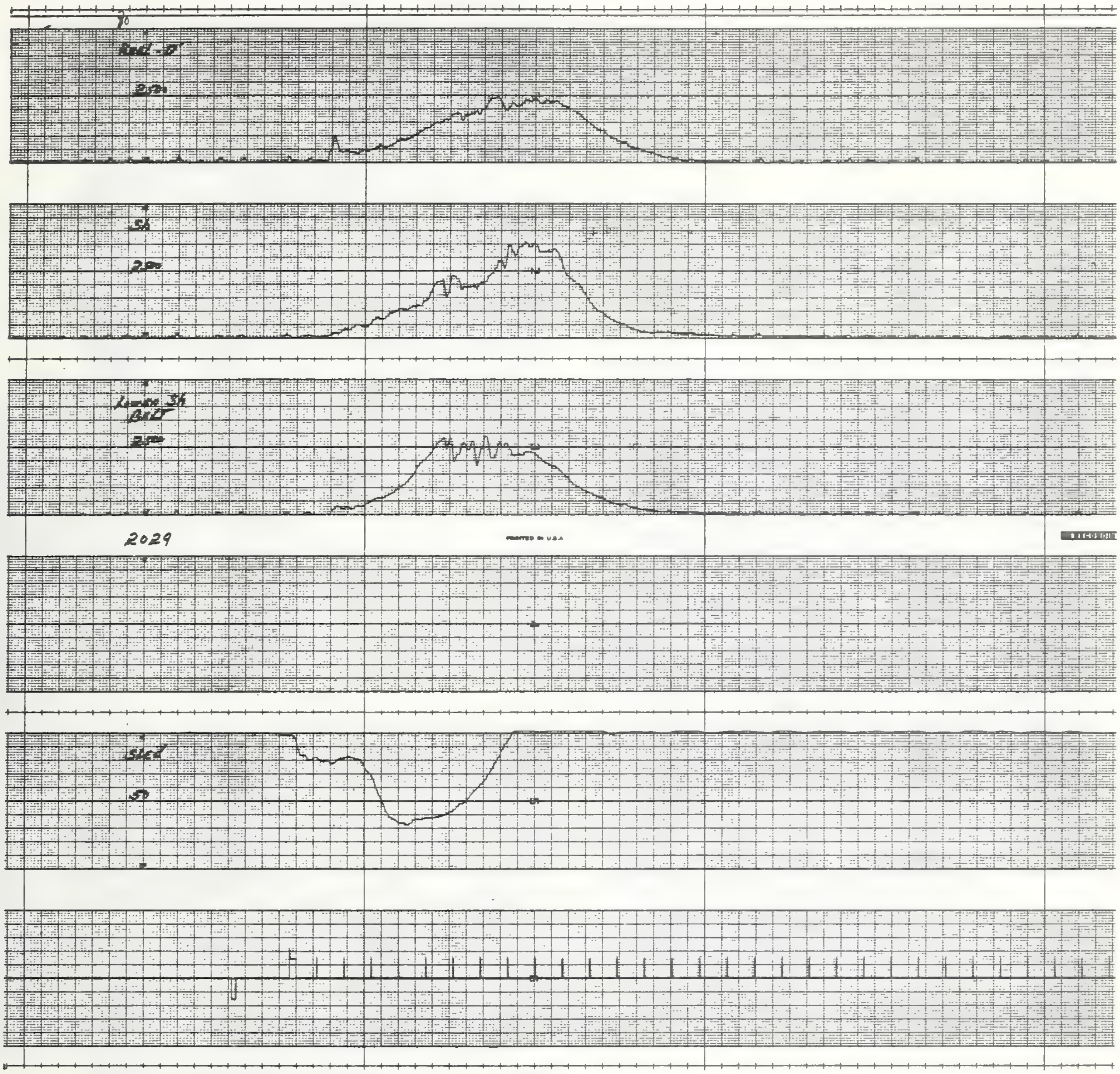
Time = 10 ms/division



Time = 10 ms/division



Time = 10 ms/division

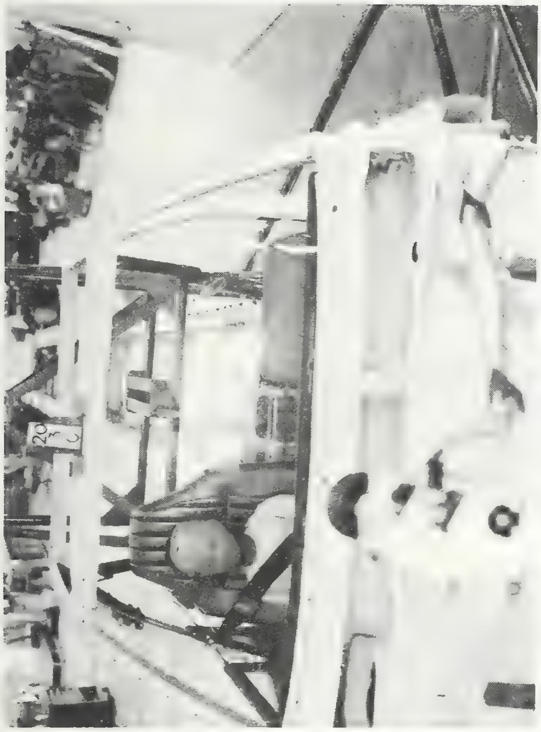


Time = 10 ms/division

PRETEST

POST TEST

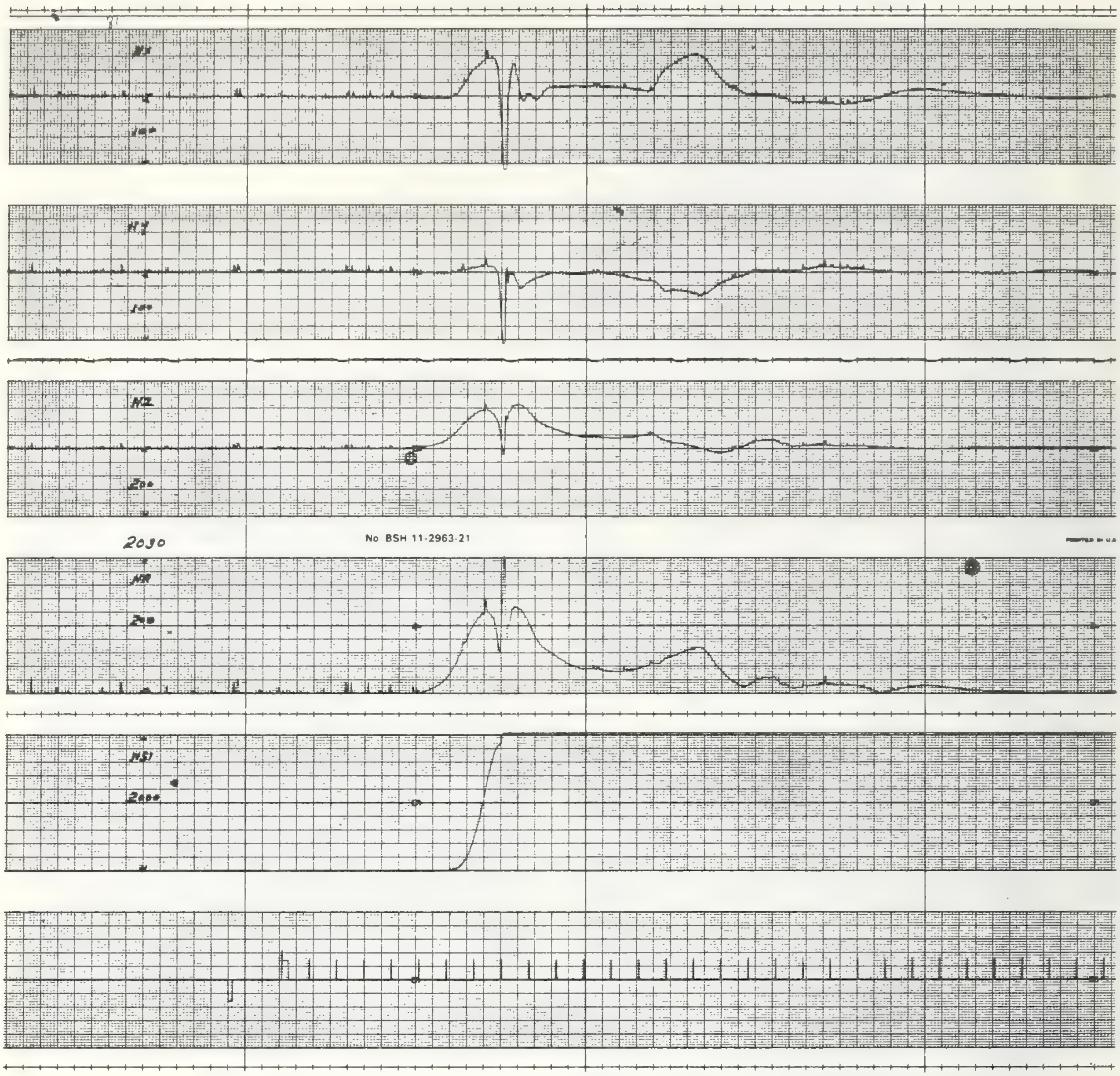
RUN 2030



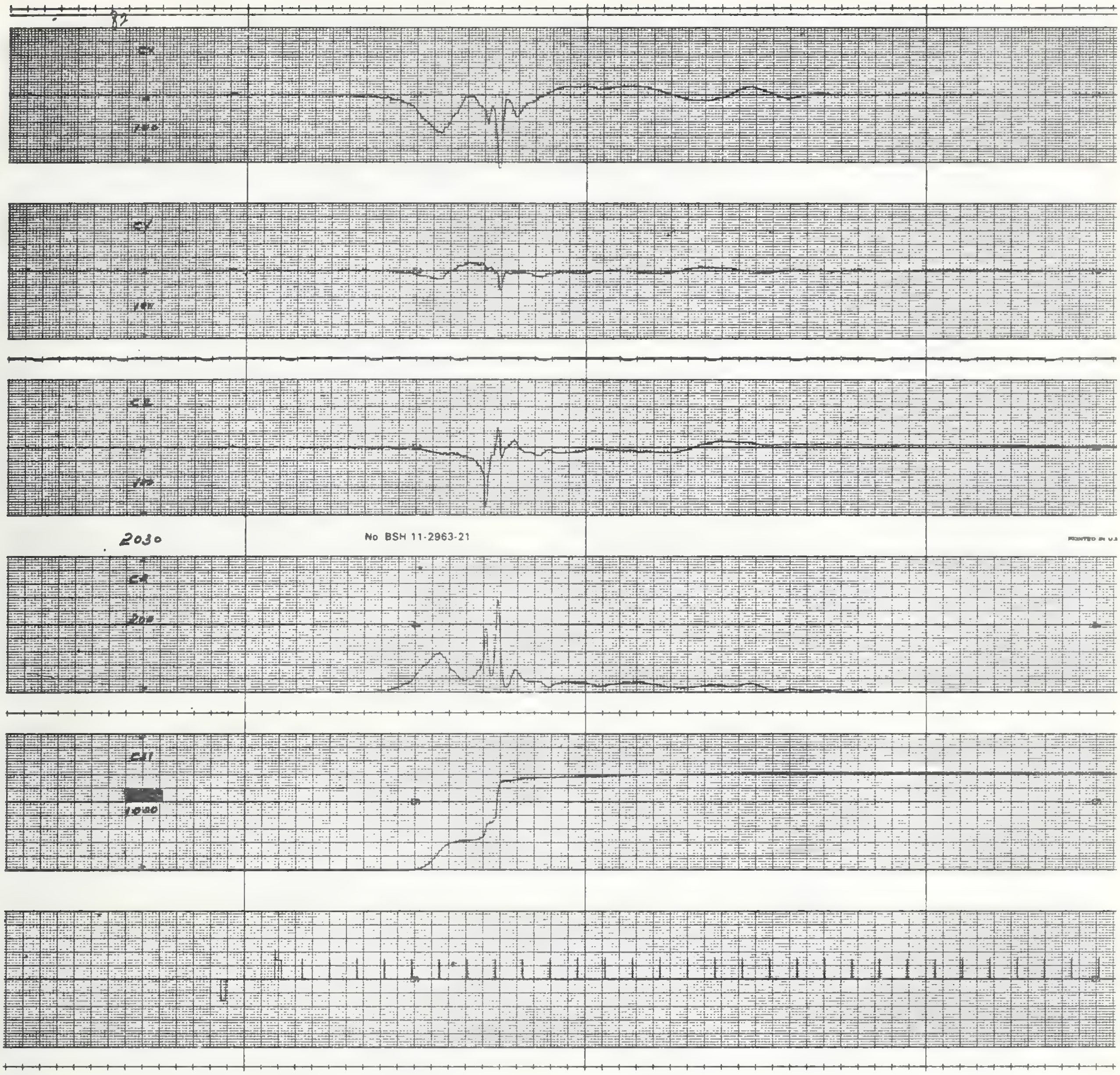
PRETEST

POST TEST

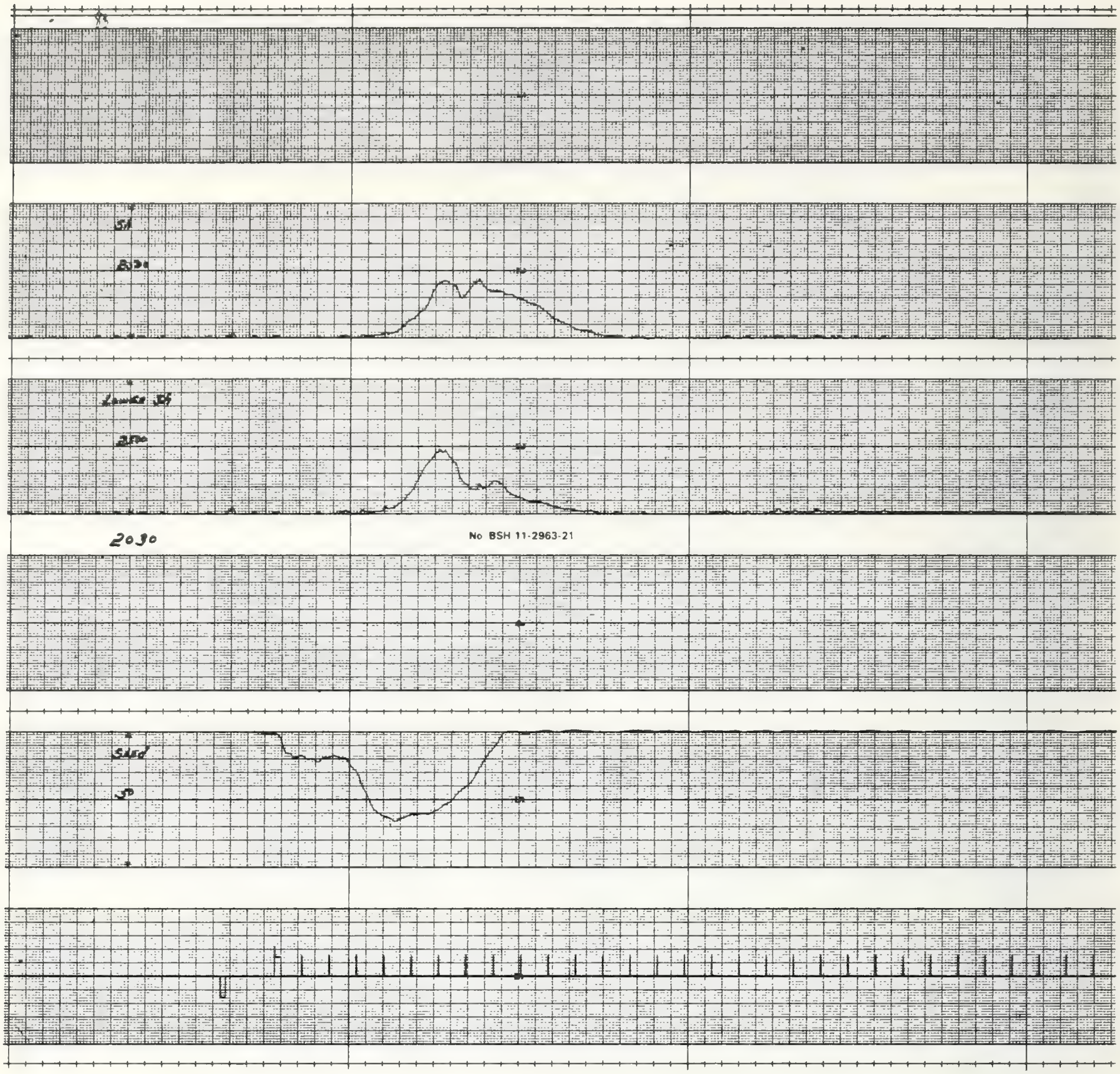
RUN 2030



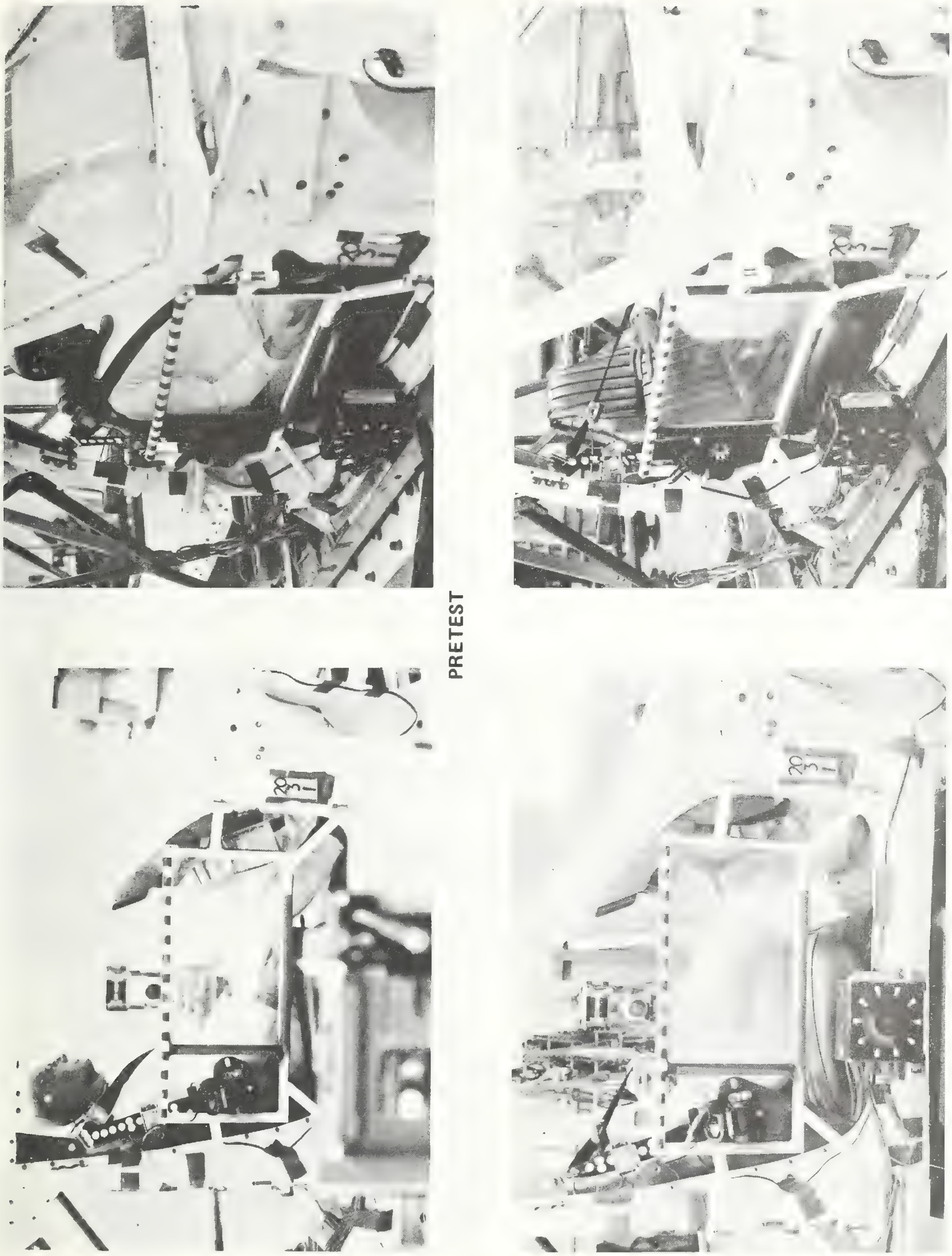
Time = 10 ms/division



Time = 10 ms/division



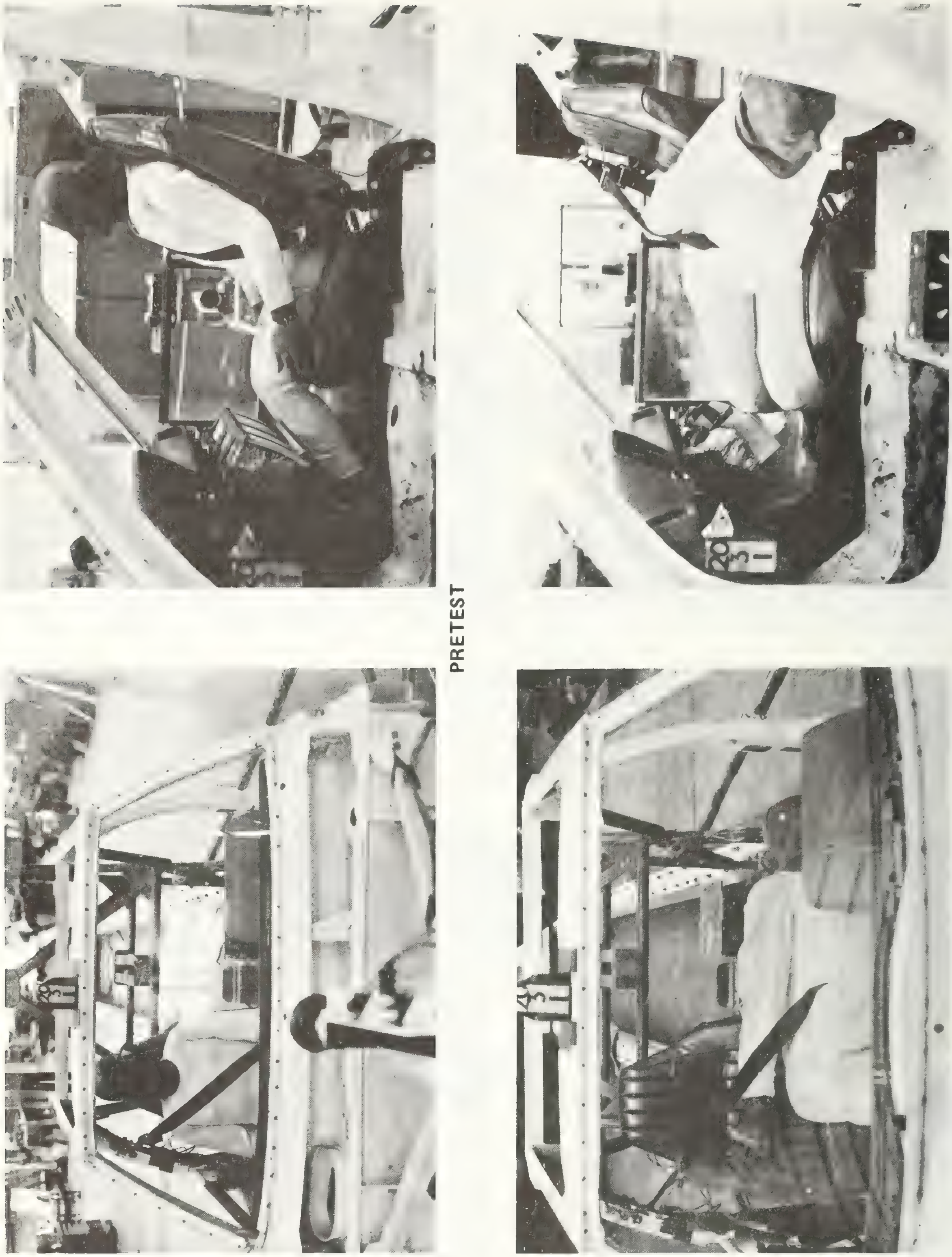
Time = 10 ms/division



PRETEST

POST TEST

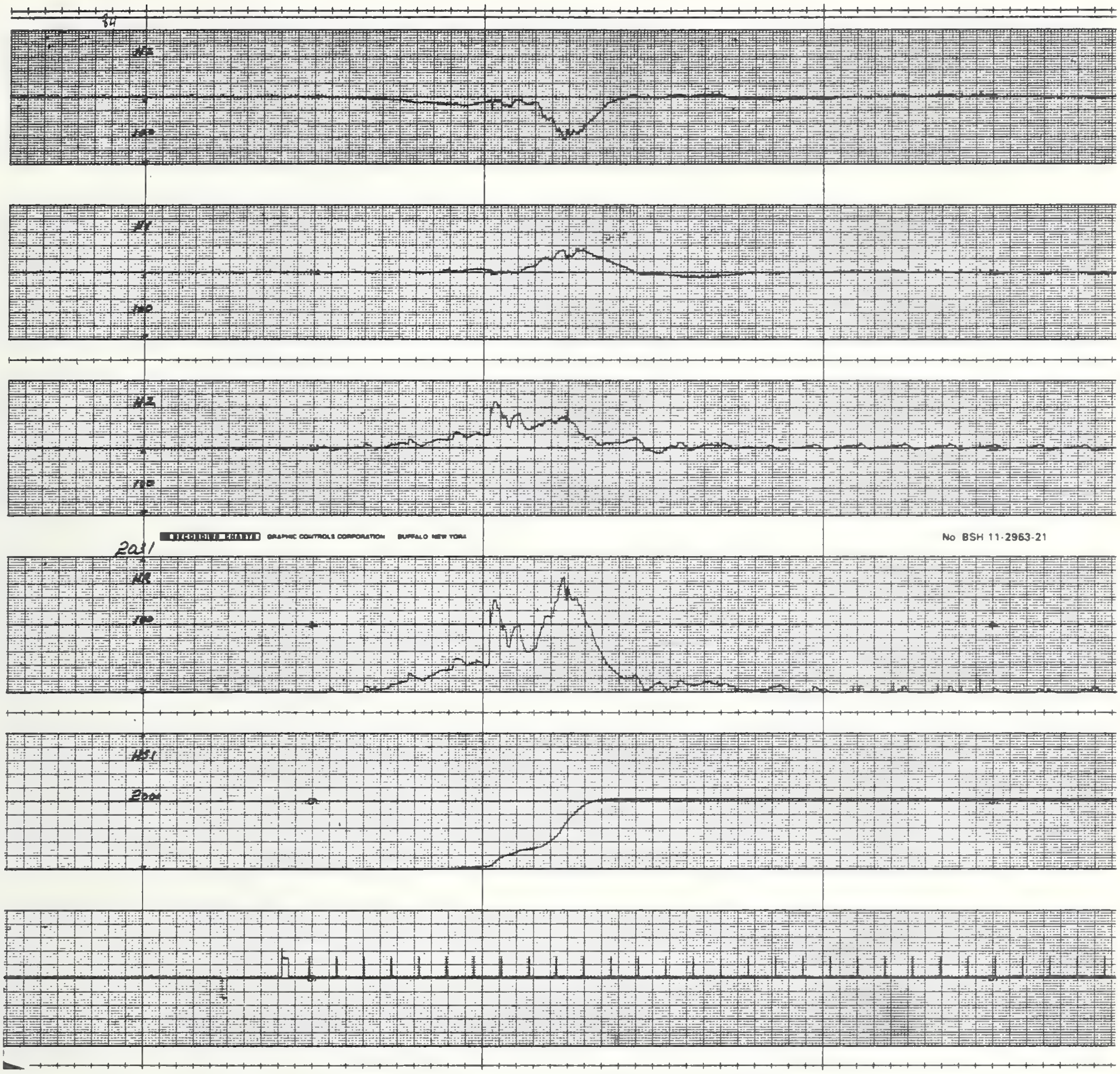
RUN 2031



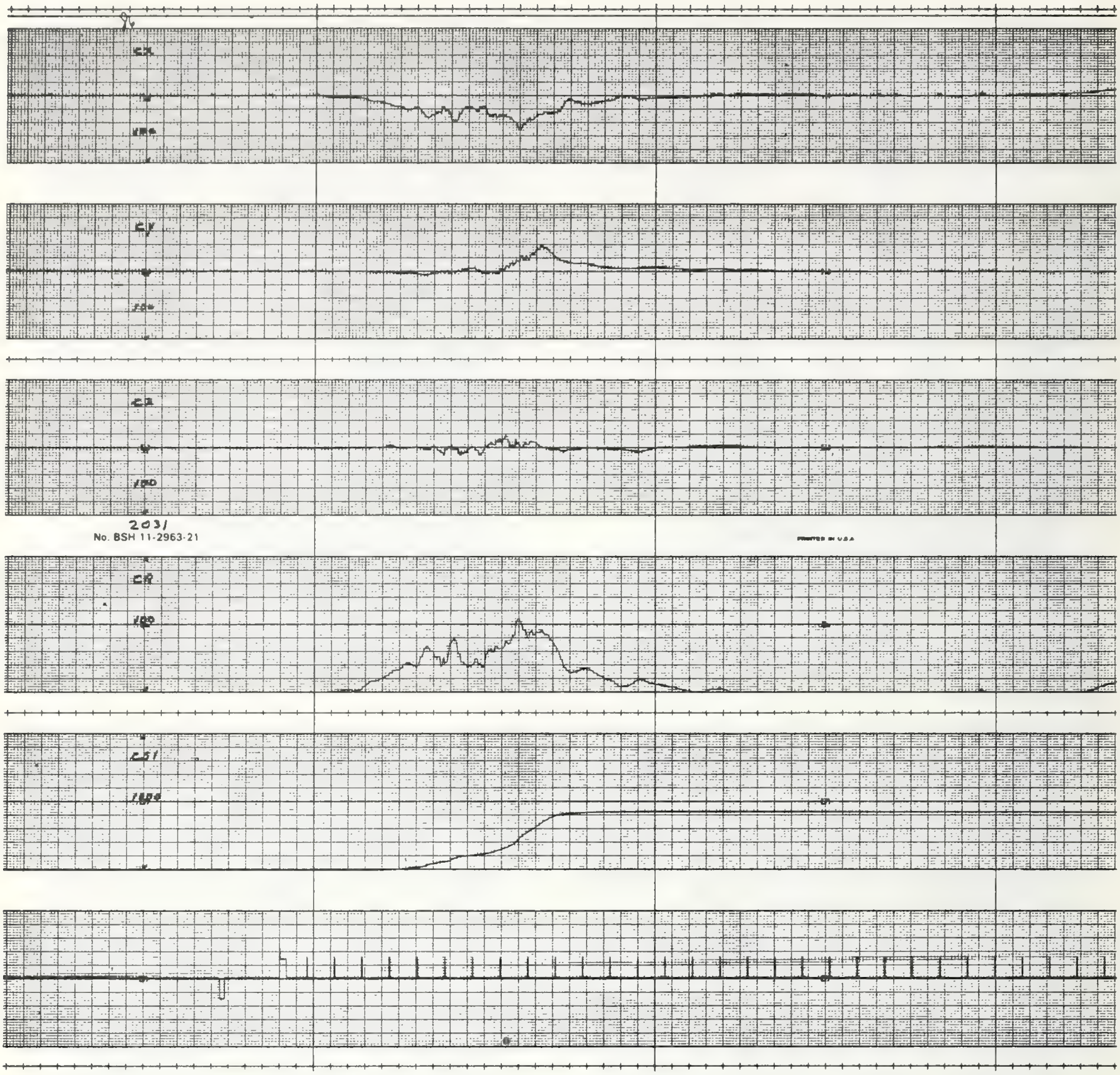
PRETEST

POST TEST

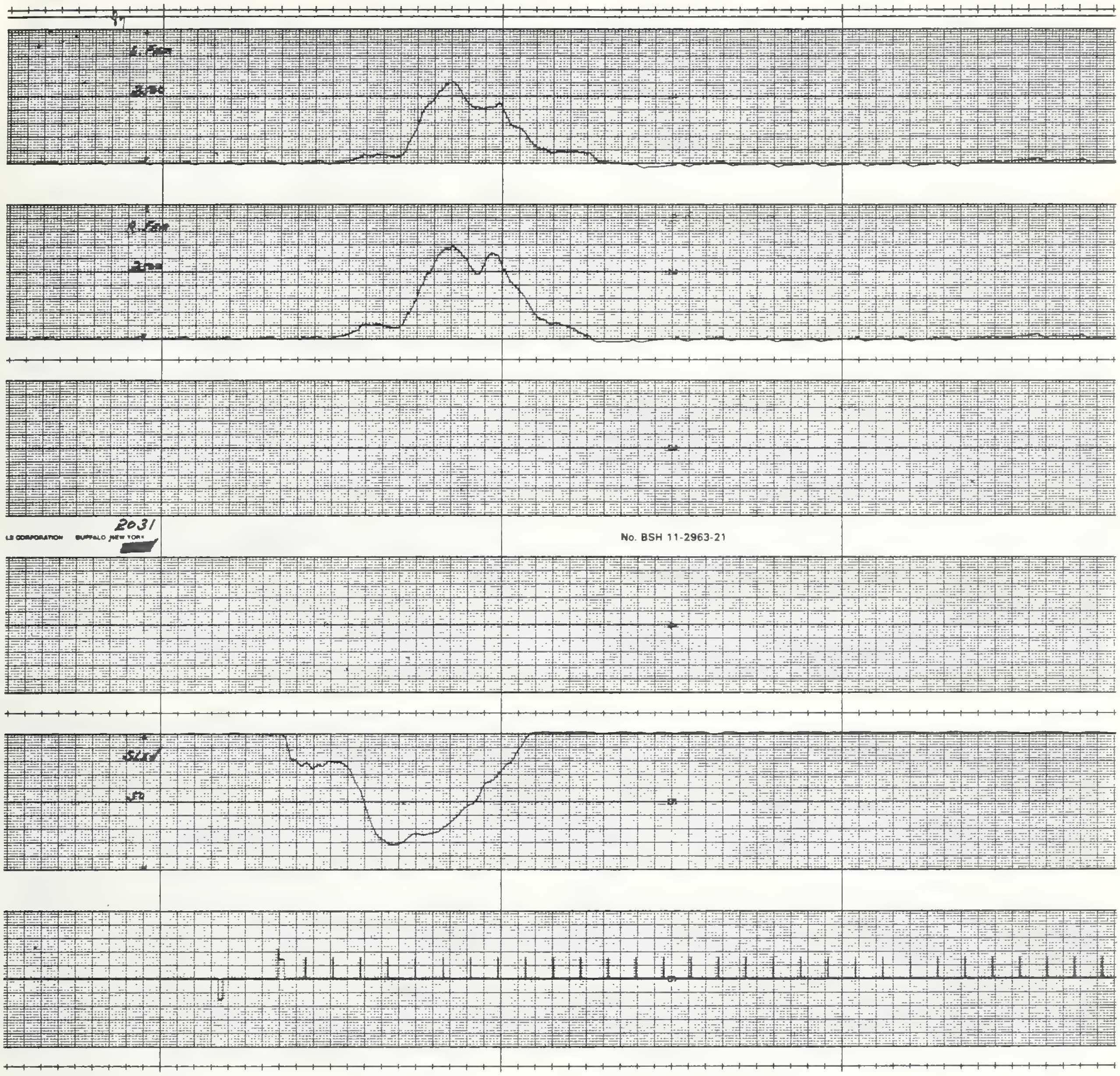
RUN 2031



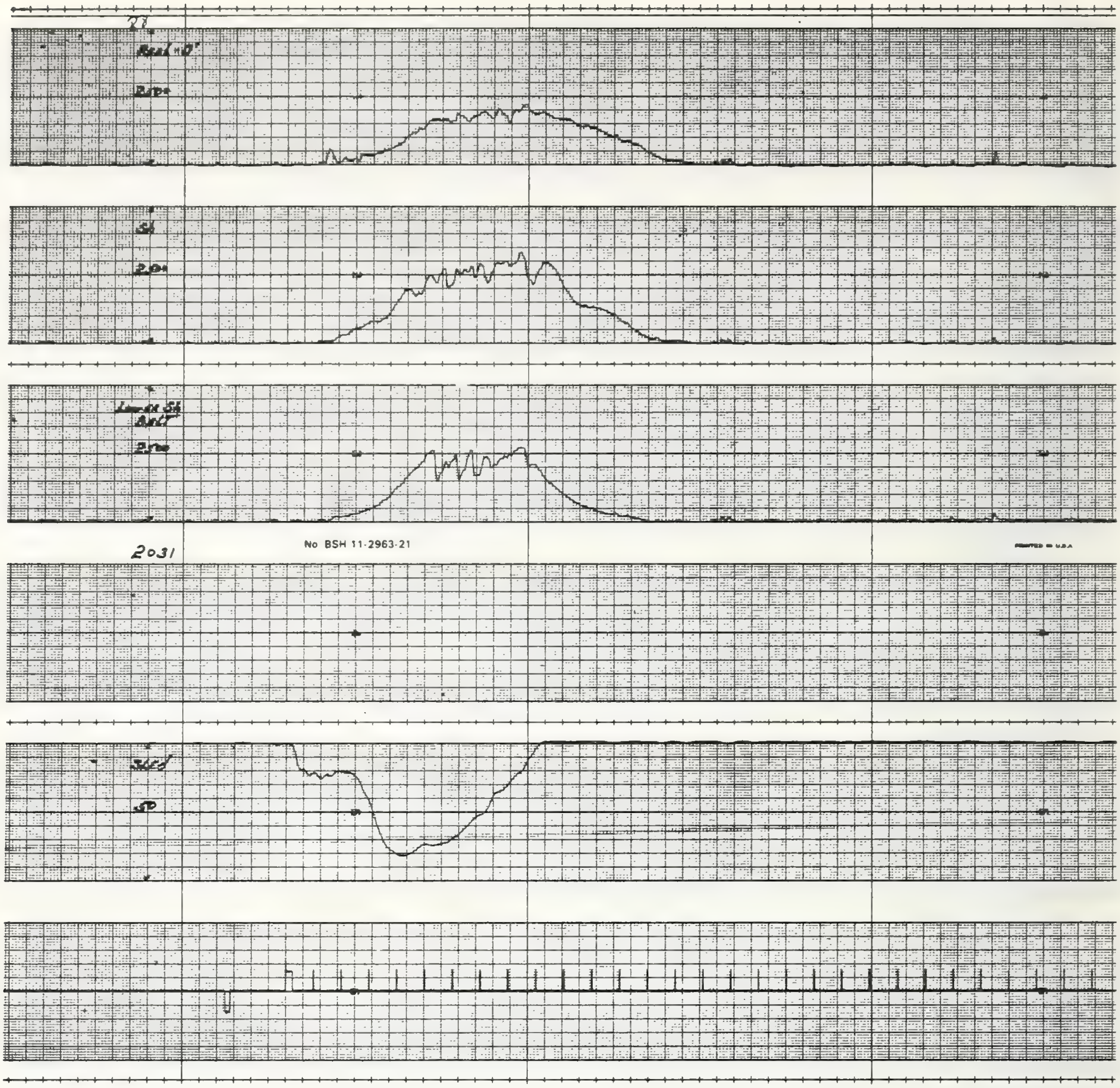
Time = 10 ms/division



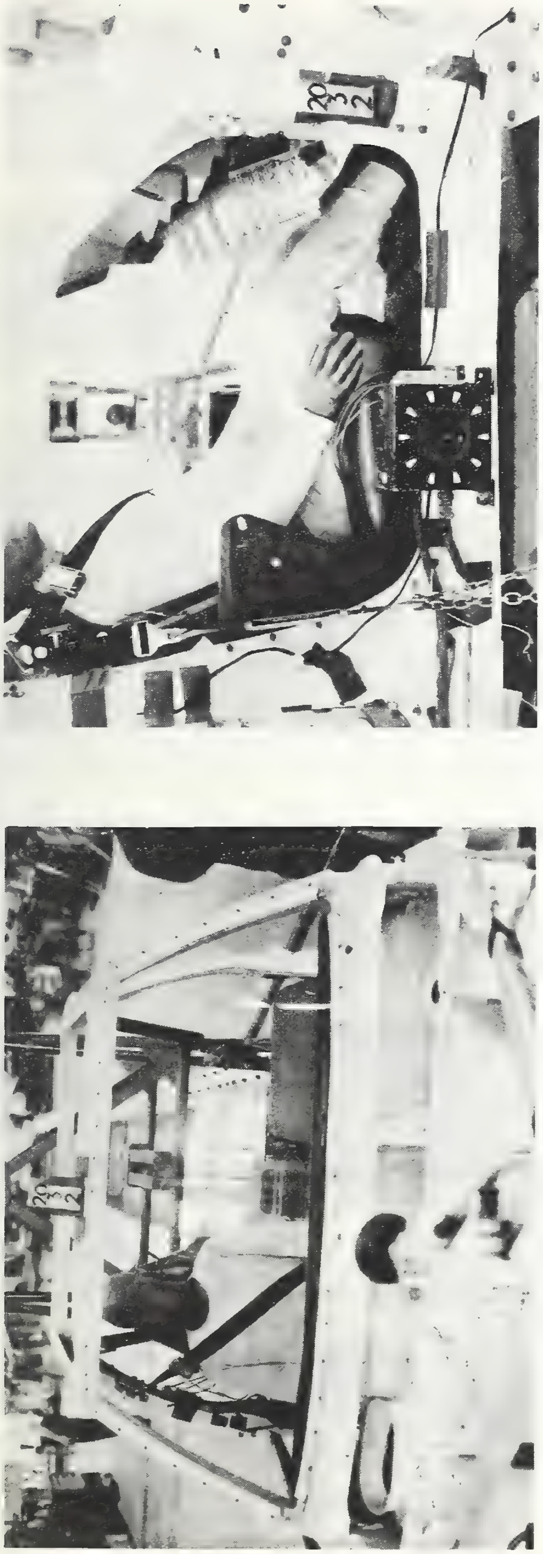
Time = 10 ms/division



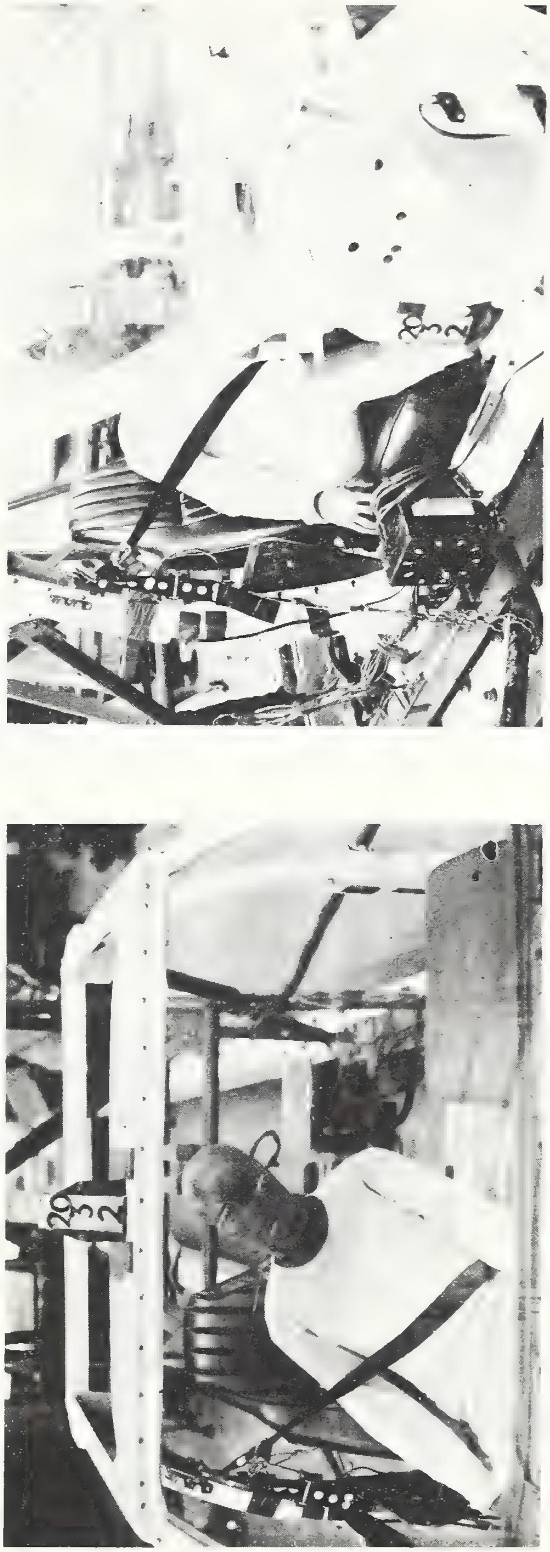
Time = 10 ms/division



Time = 10 ms/division



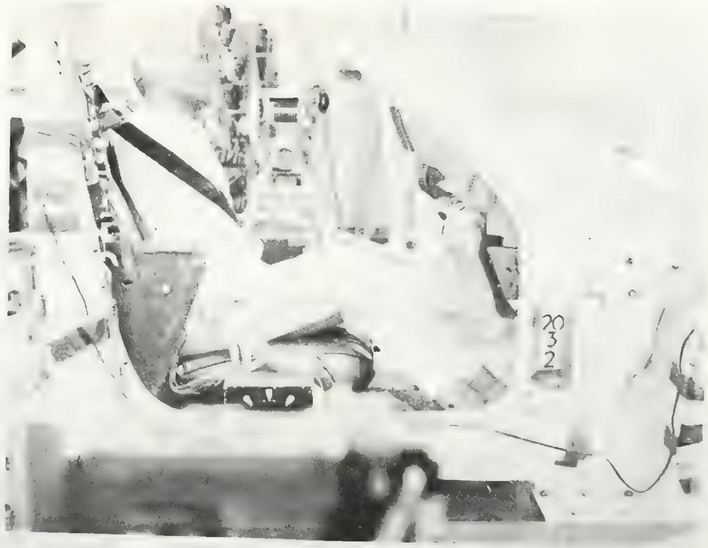
PRETEST

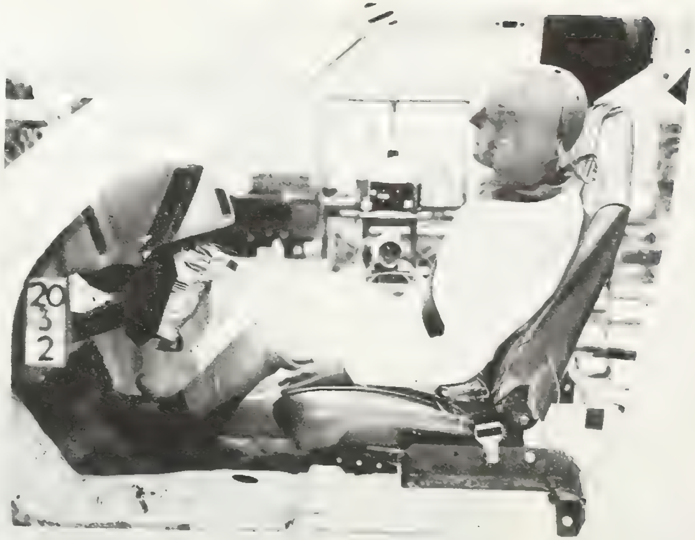


POST TEST

RUN 2032

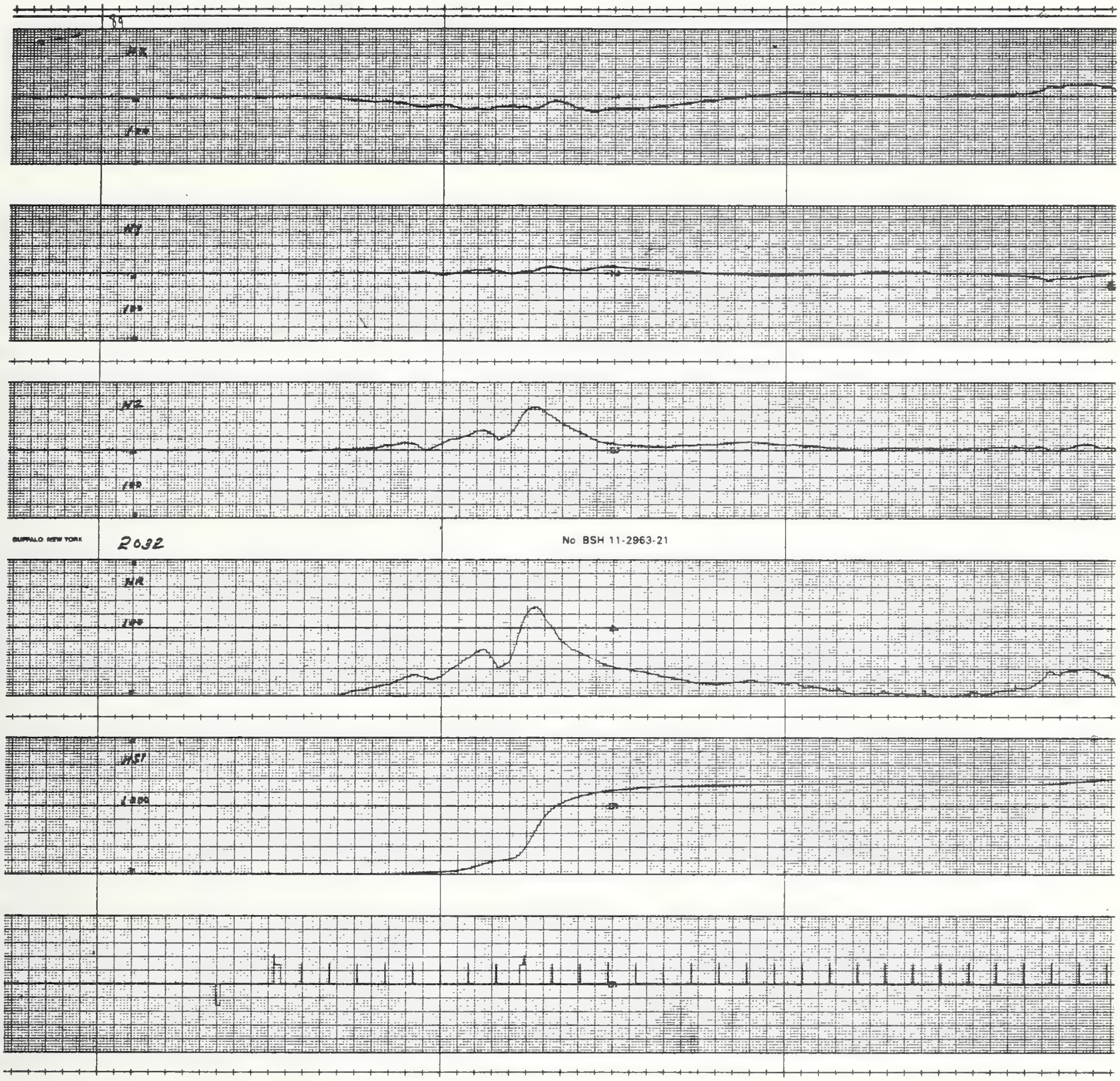
PRETEST



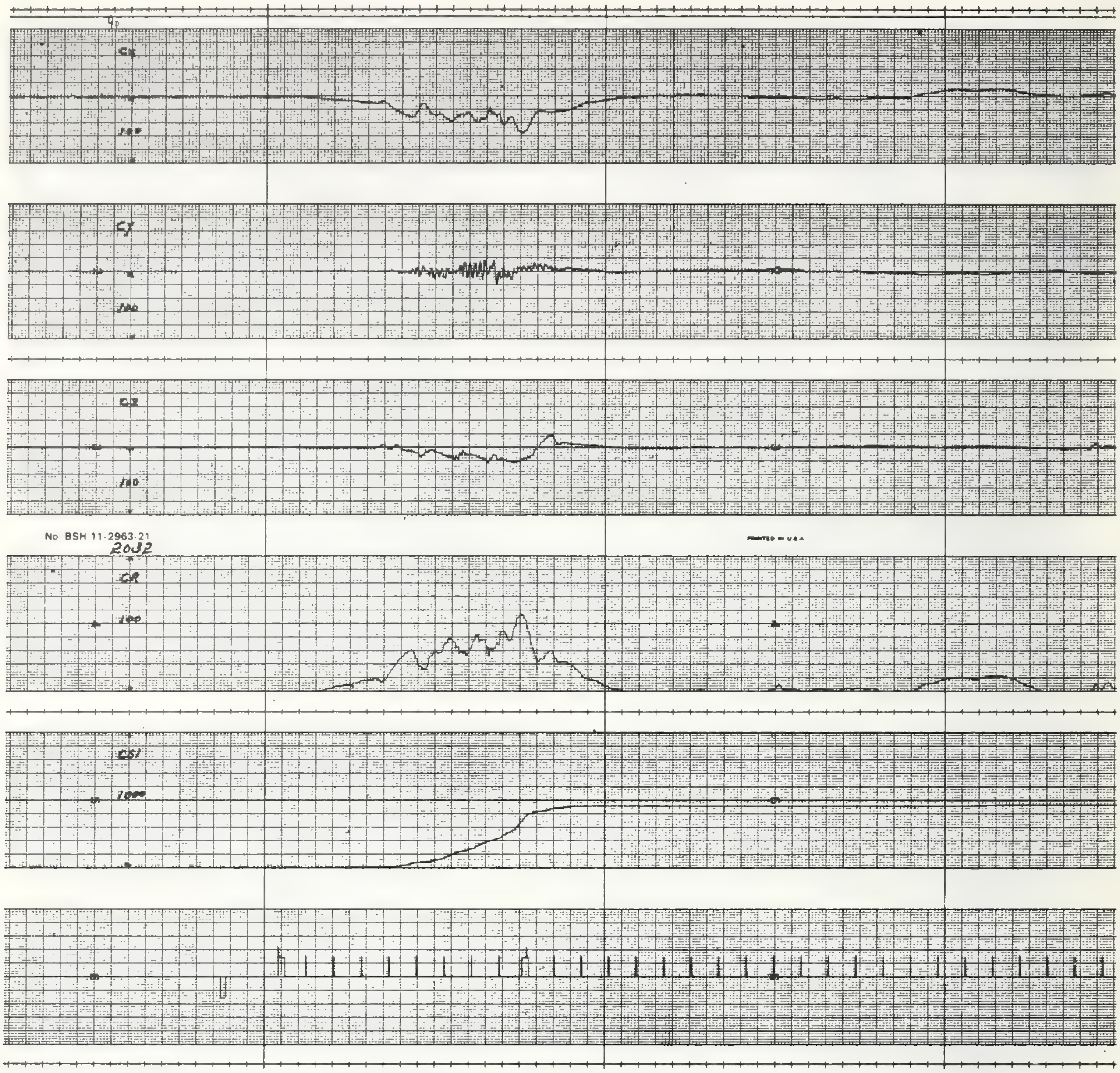


POST TEST

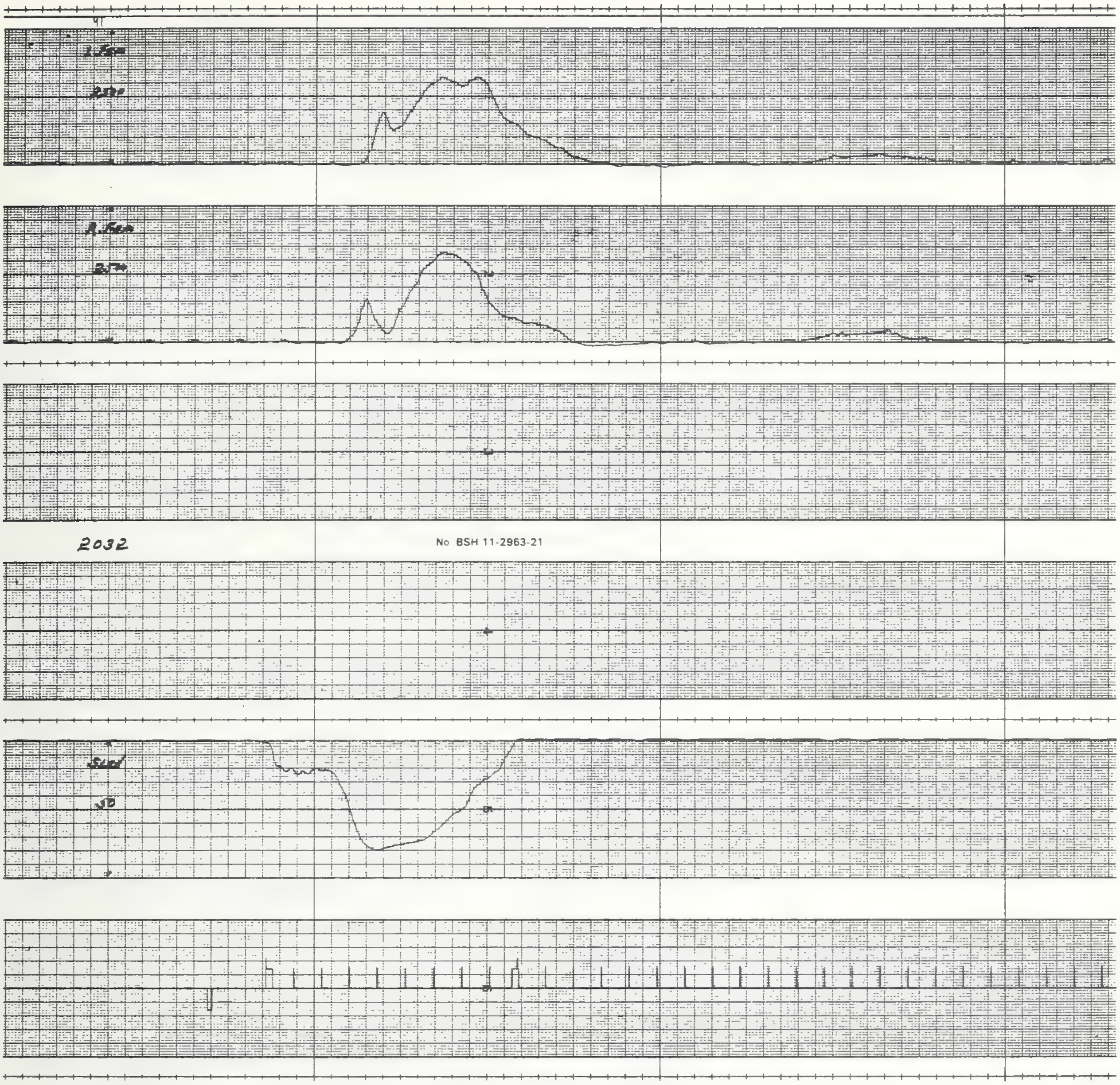
RUN 2032



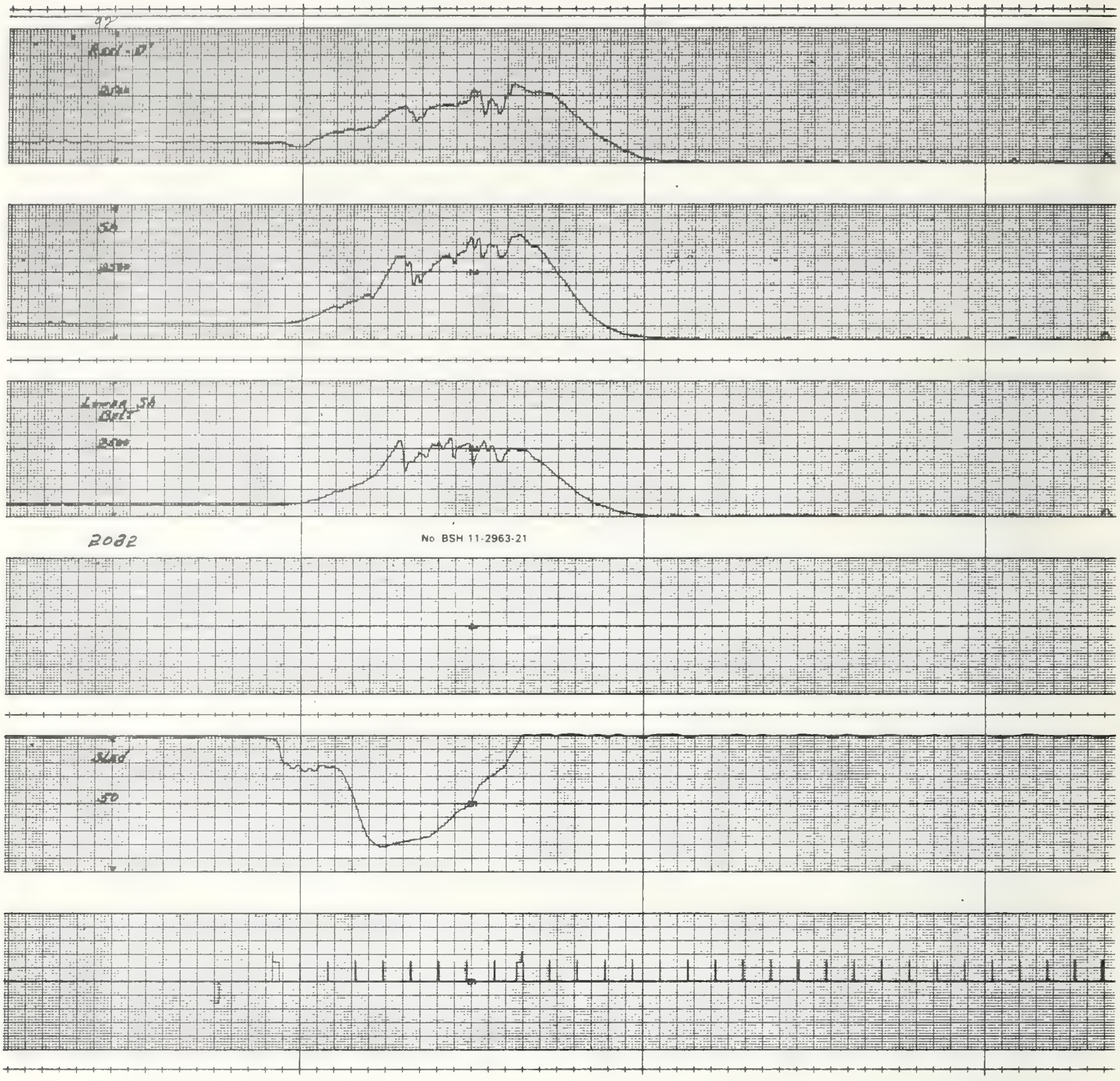
Time = 10 ms/division



Time = 10 ms/division



Time = 10 ms/division

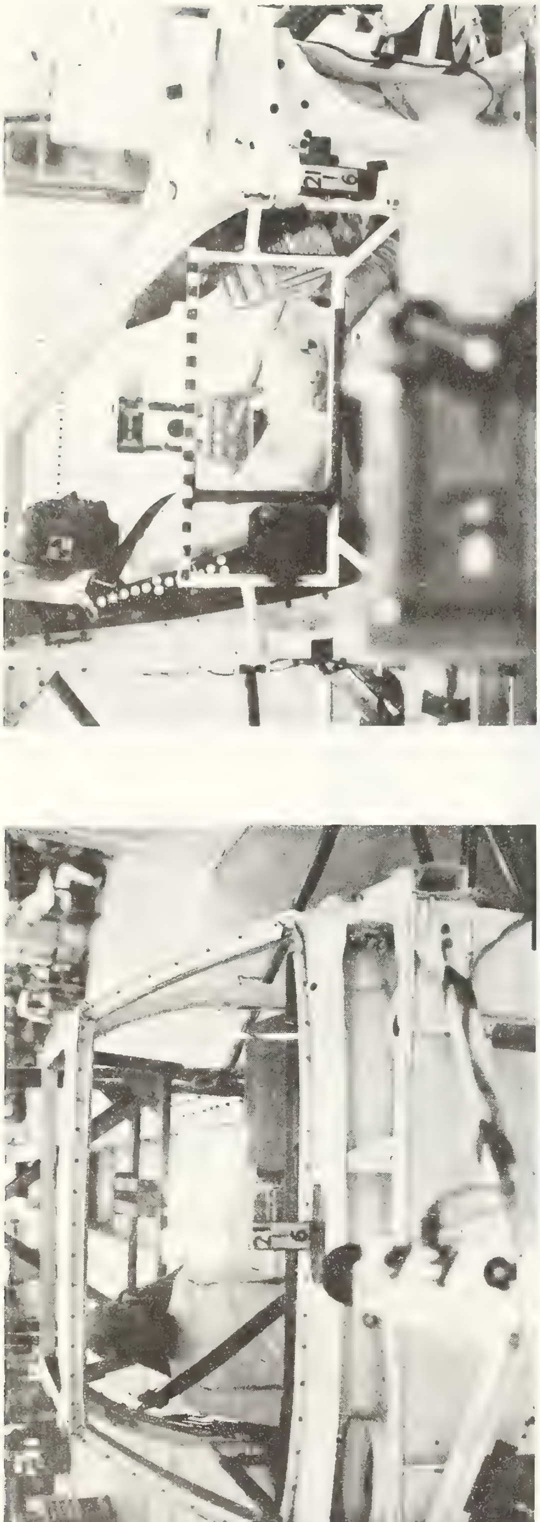


Time = 10 ms/division

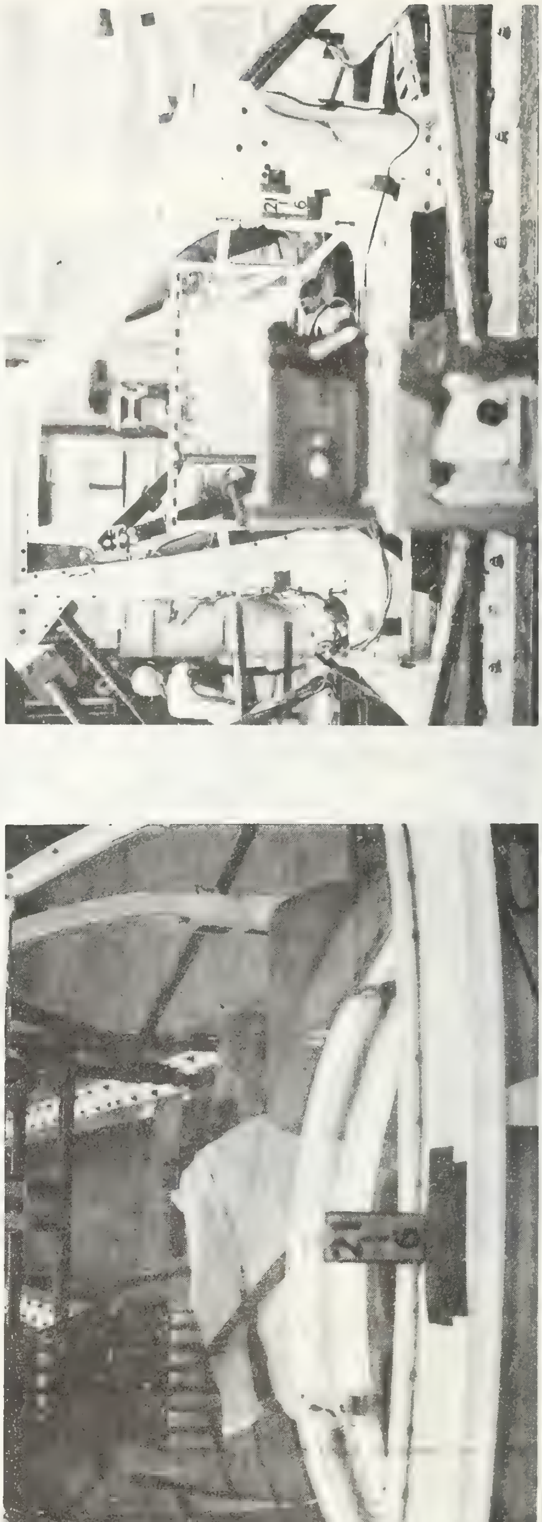
1 2 3 4

6 7 8 5

RUN 2116 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

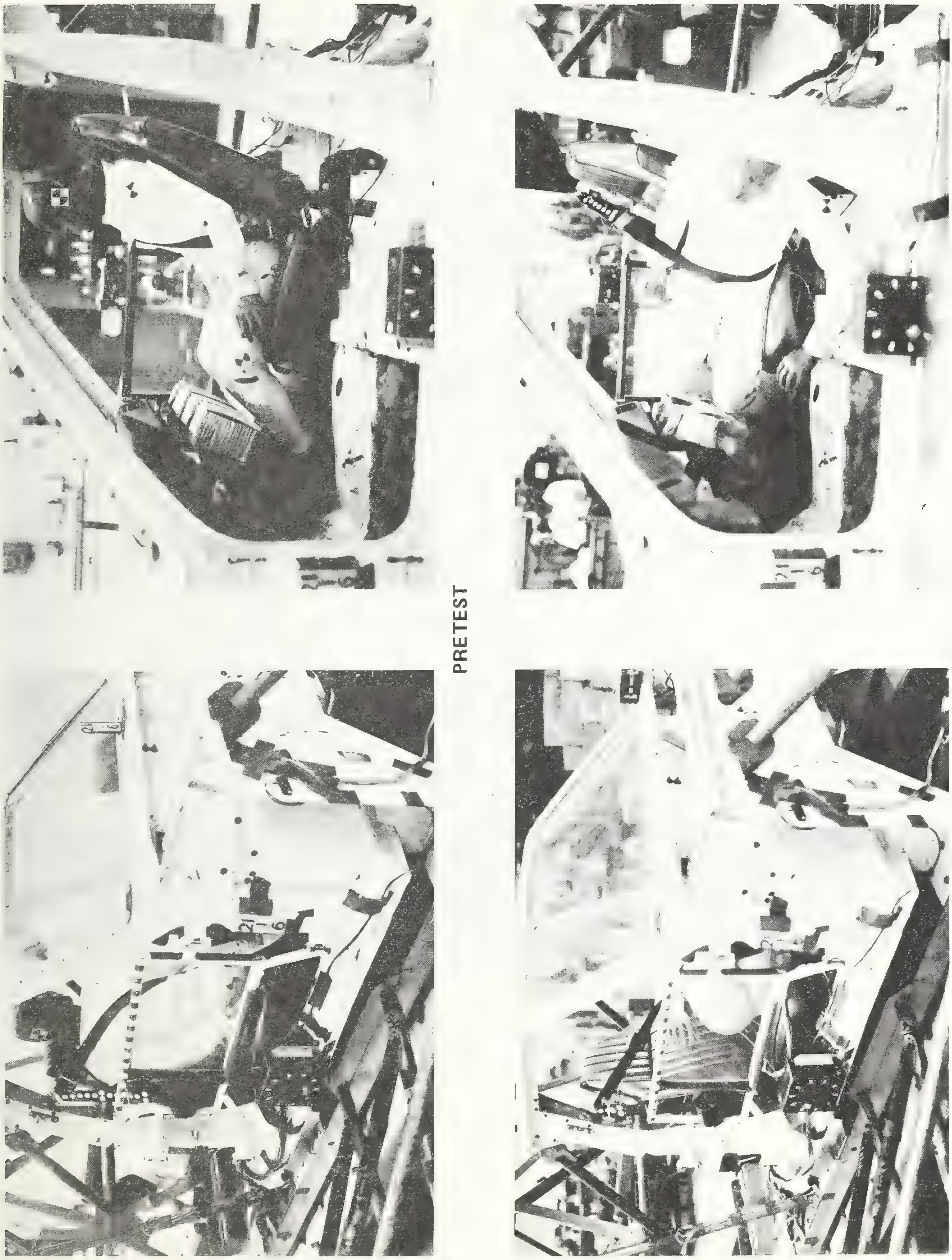


PRETEST



POST TEST

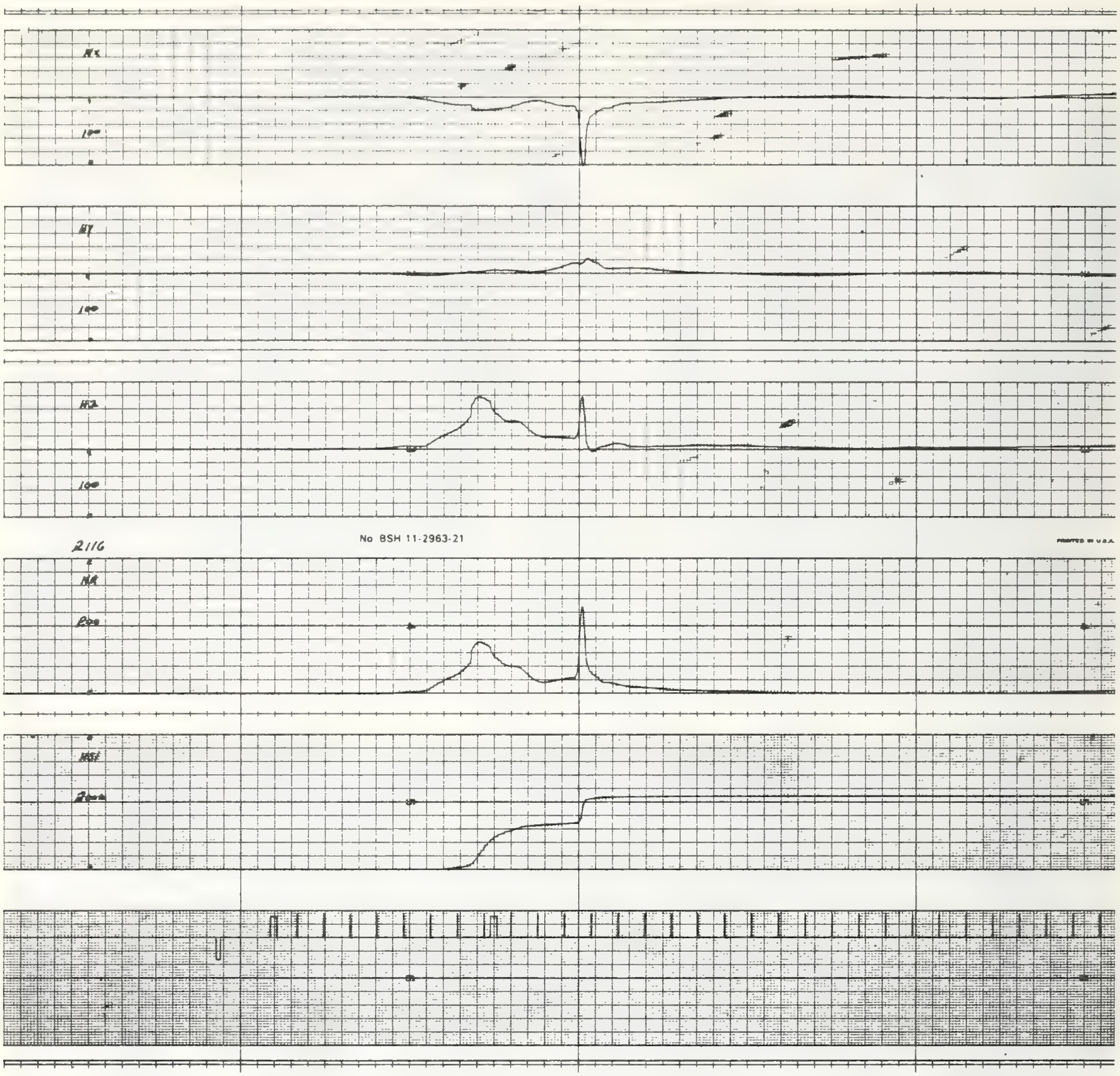
RUN 2116



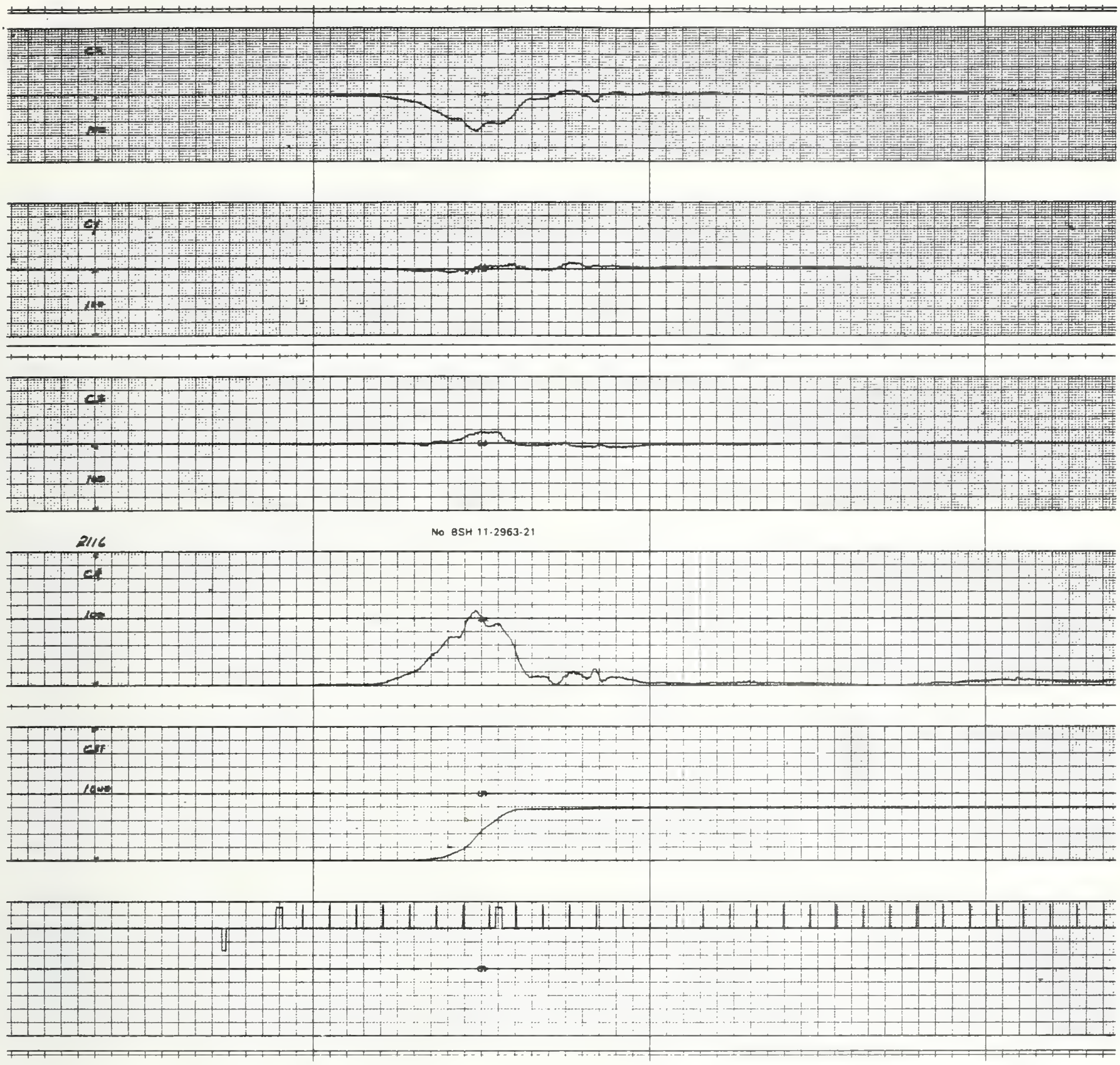
PRETEST

POST TEST

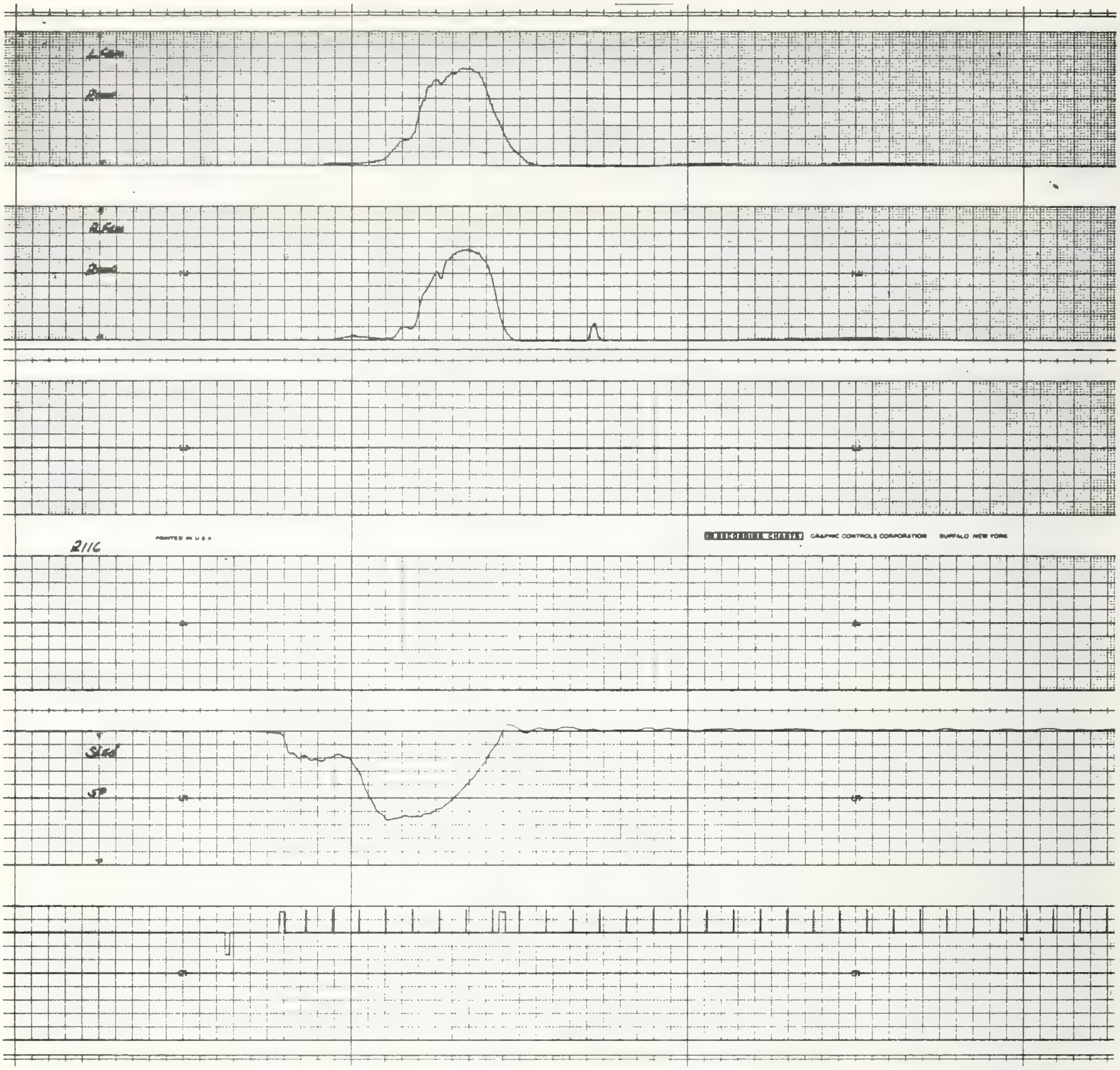
RUN 2116



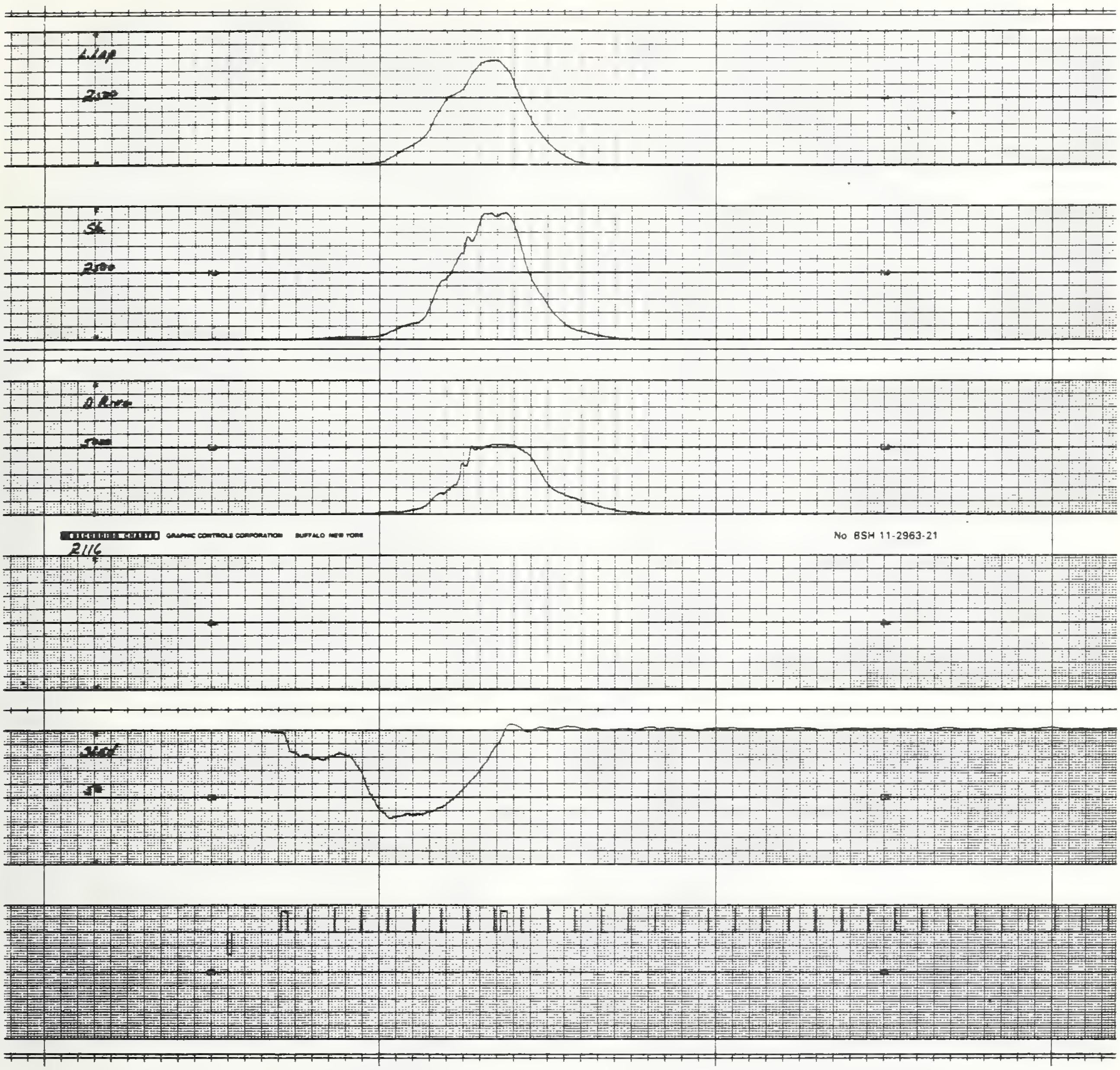
Time = 10 ms/division



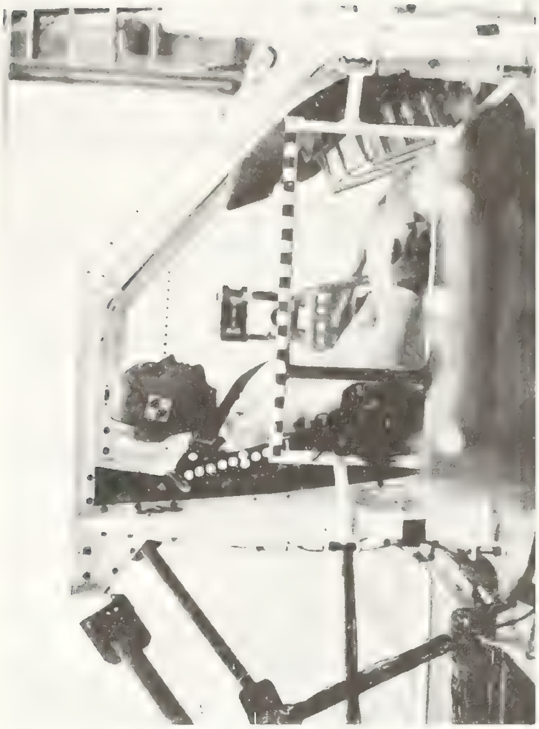
Time = 10 ms/division



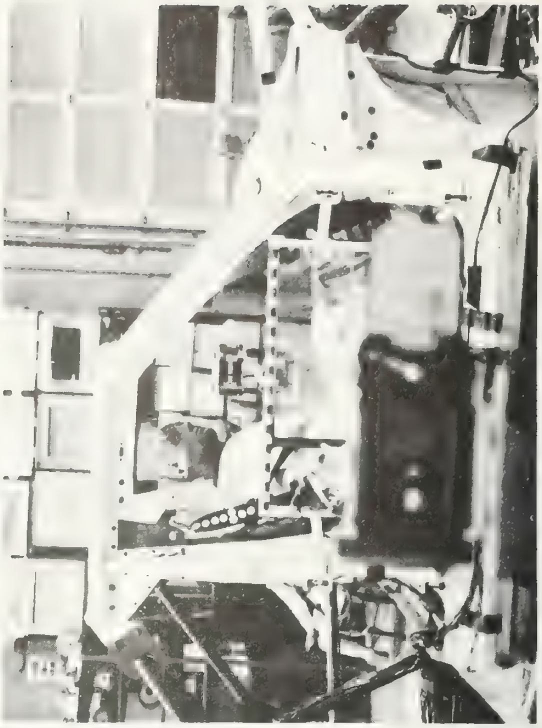
Time = 10 ms/division

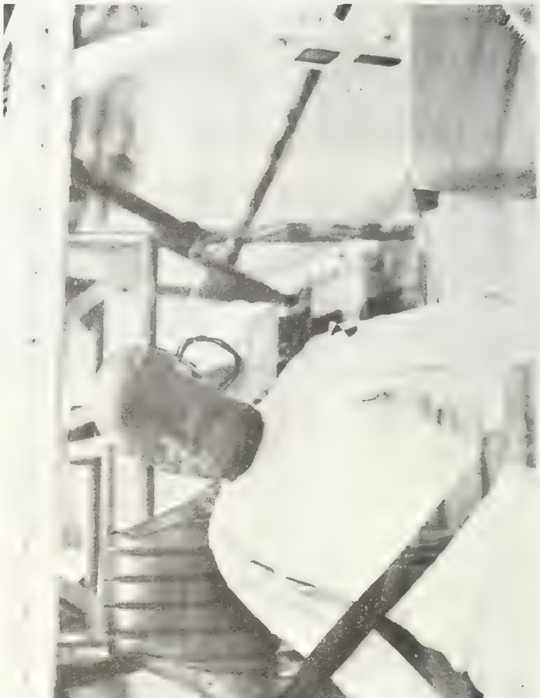


Time = 10 ms/division

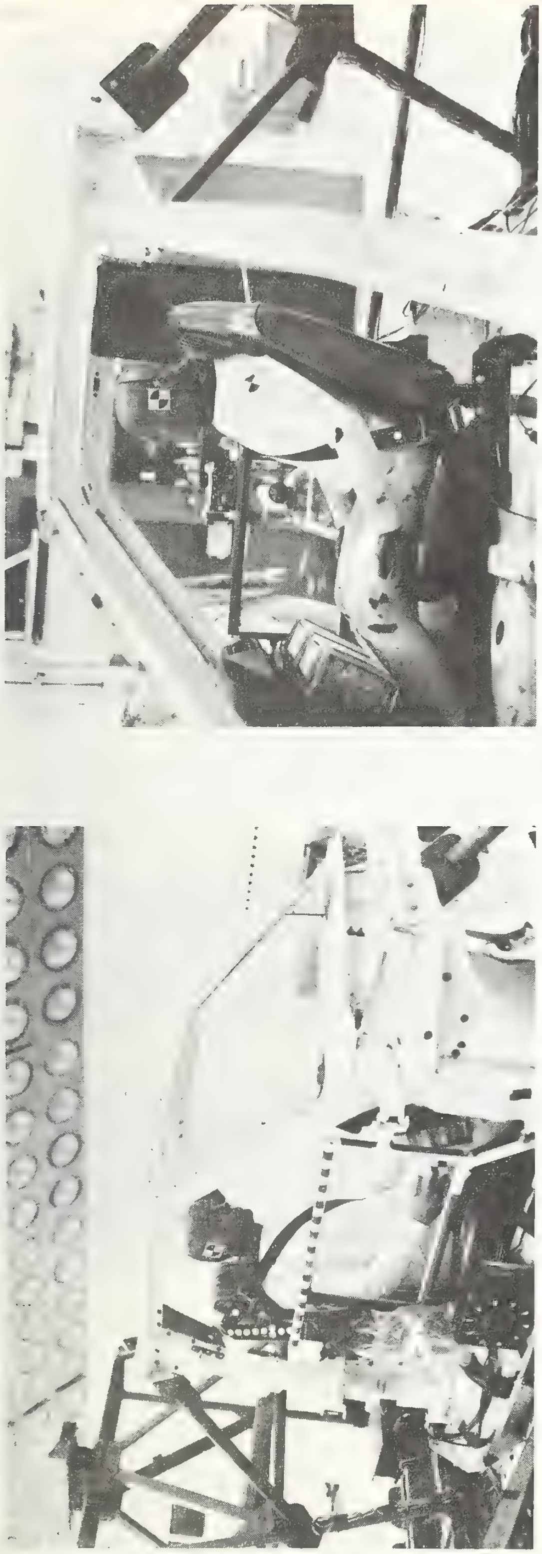


PRETEST





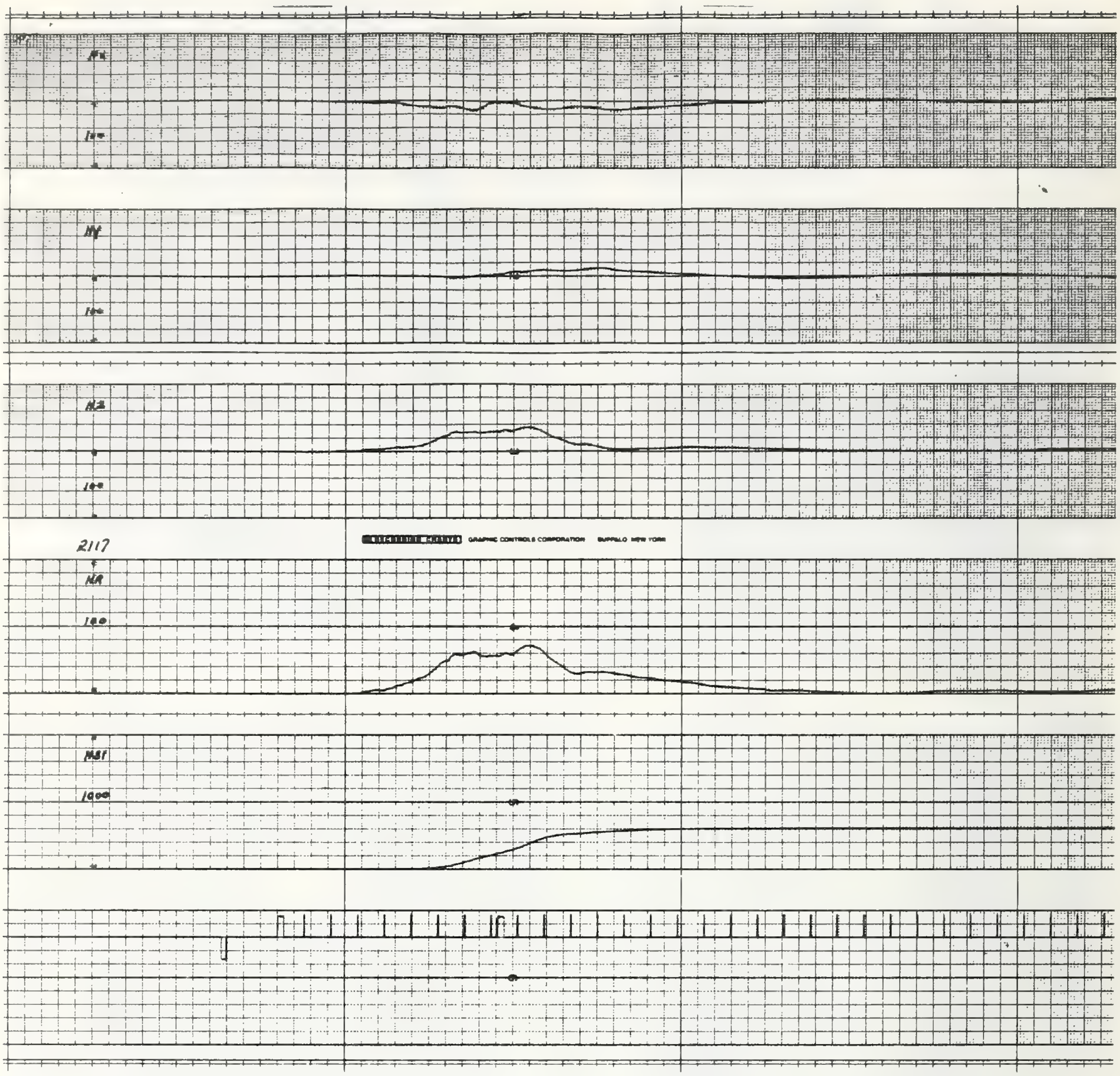
POST TEST
RUN 2117



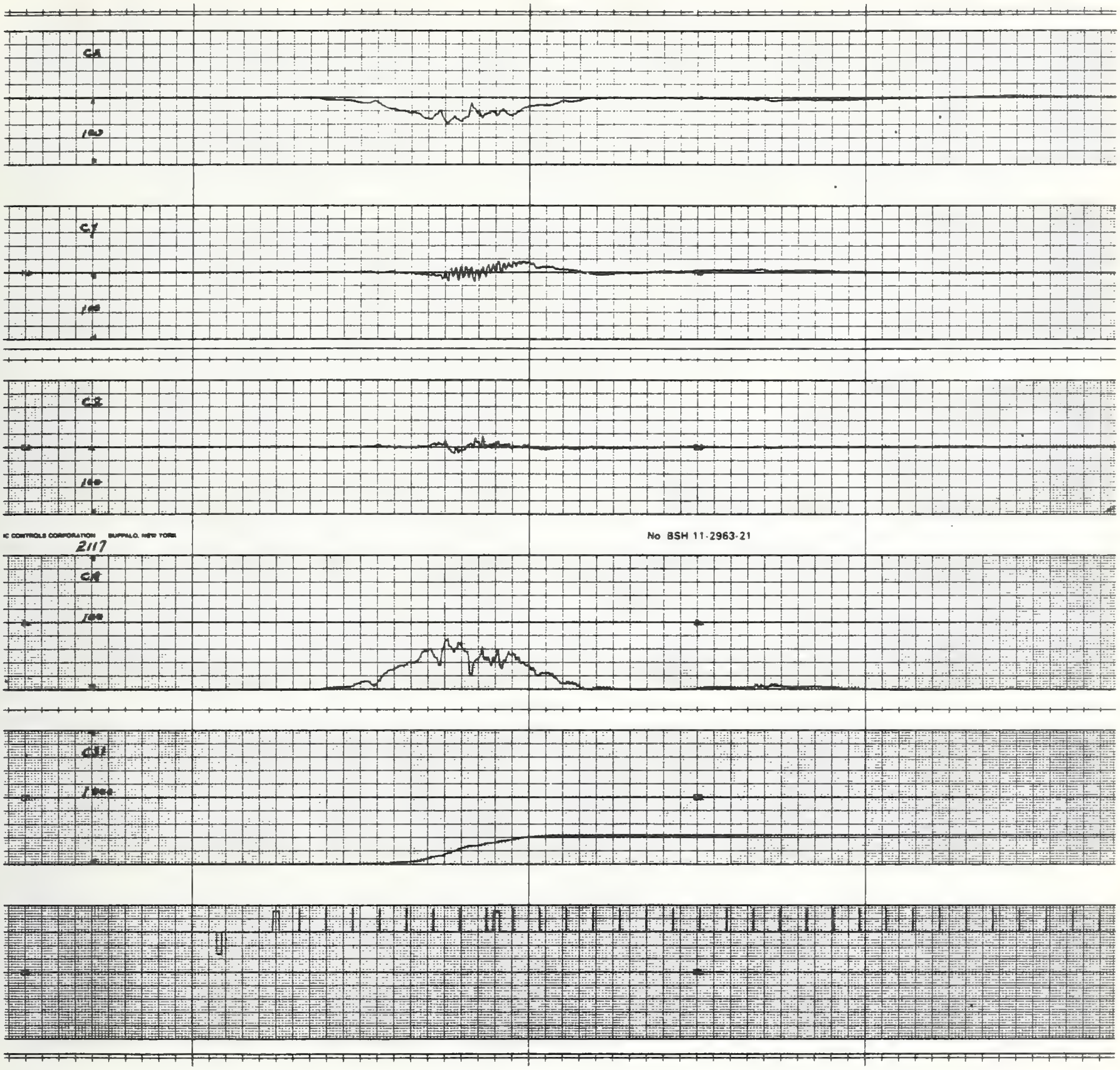
PRETEST

POST TEST

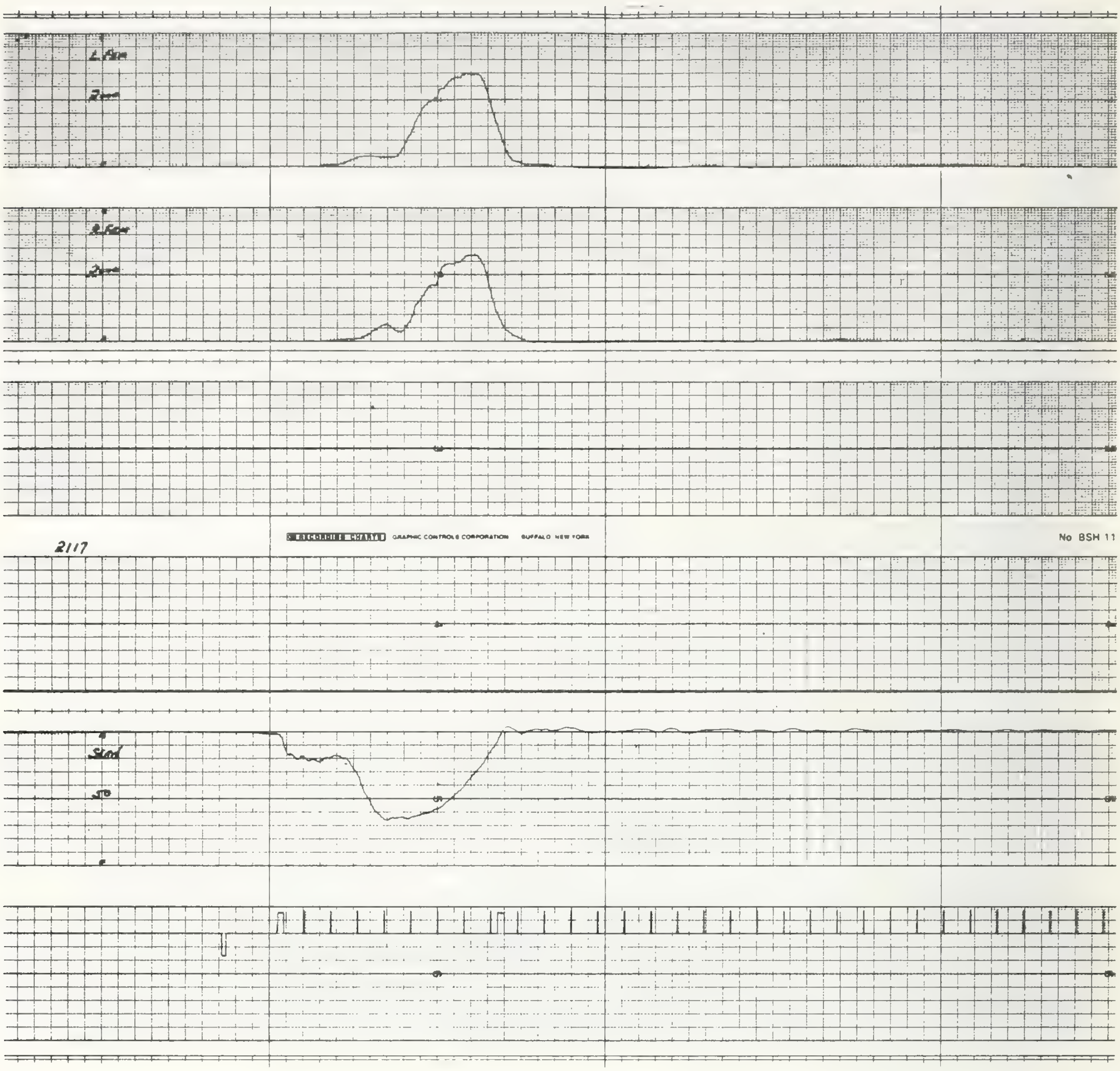
RUN 2117



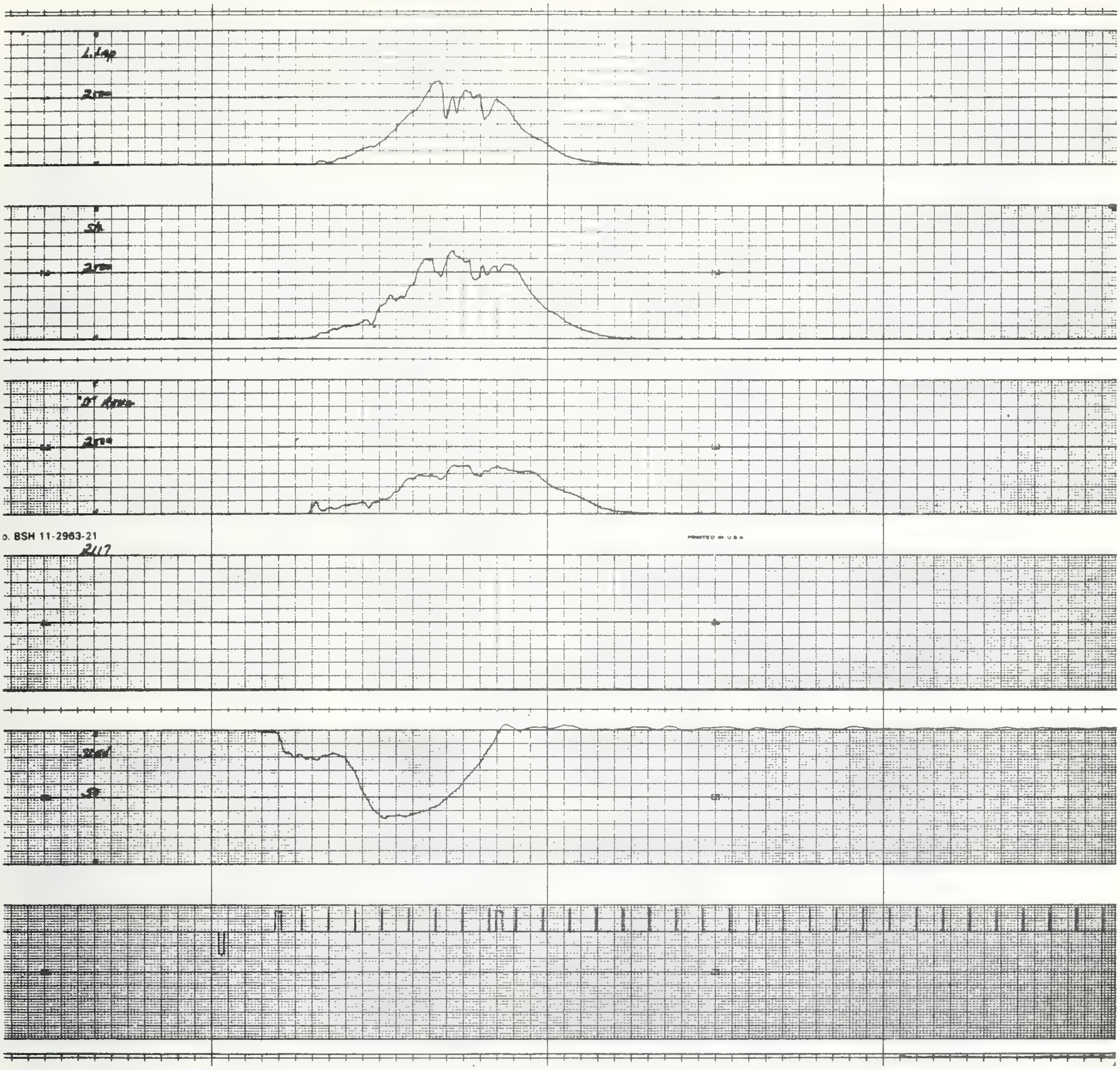
Time = 10 ms/division



Time = 10 ms/division



Time = 10 ms/division

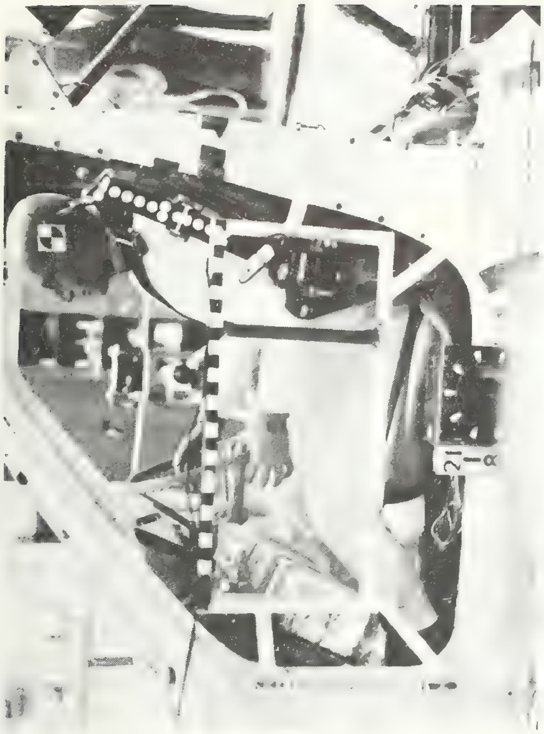
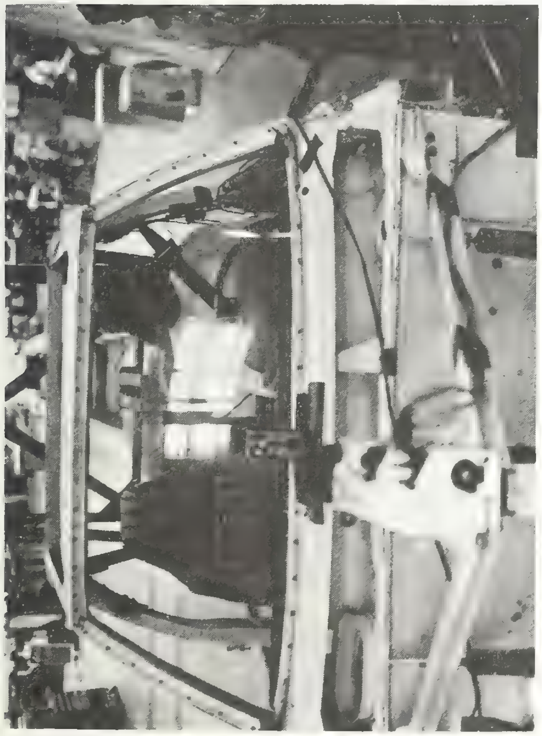


Time = 10 ms/division

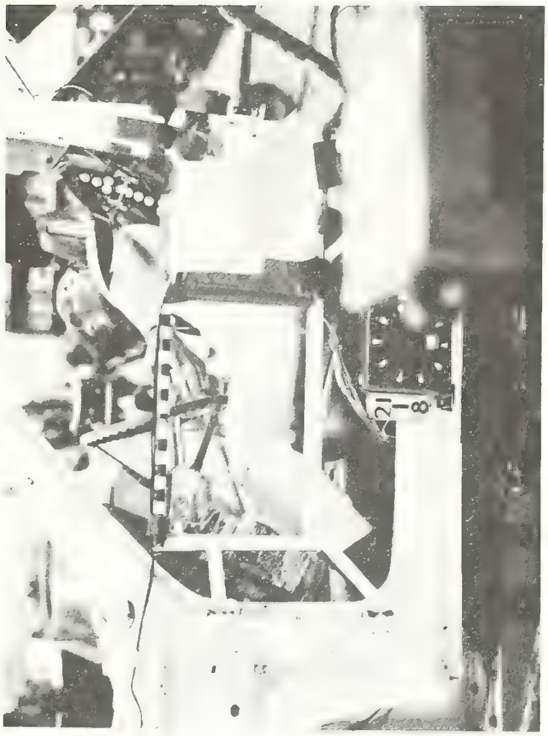
1 2 3 4

5 6 7

RUN 2118 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

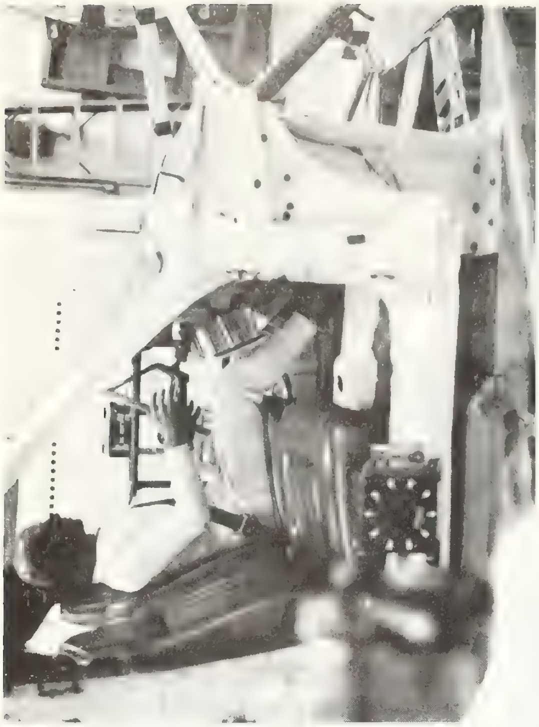



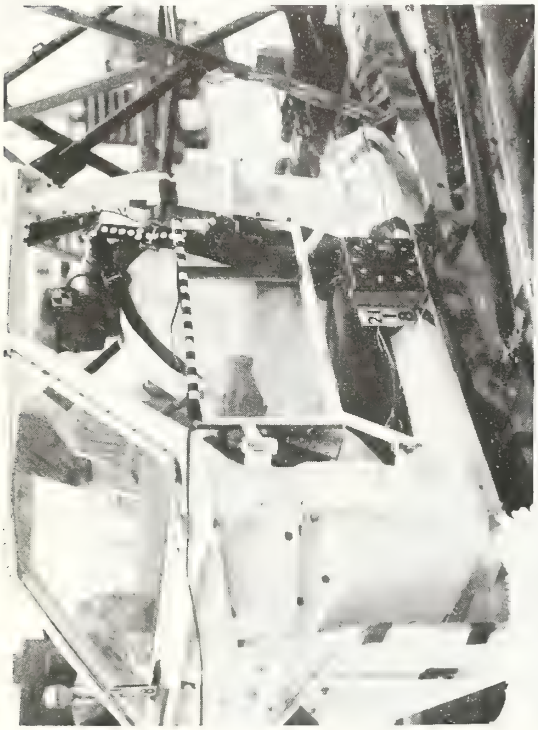
PRETEST



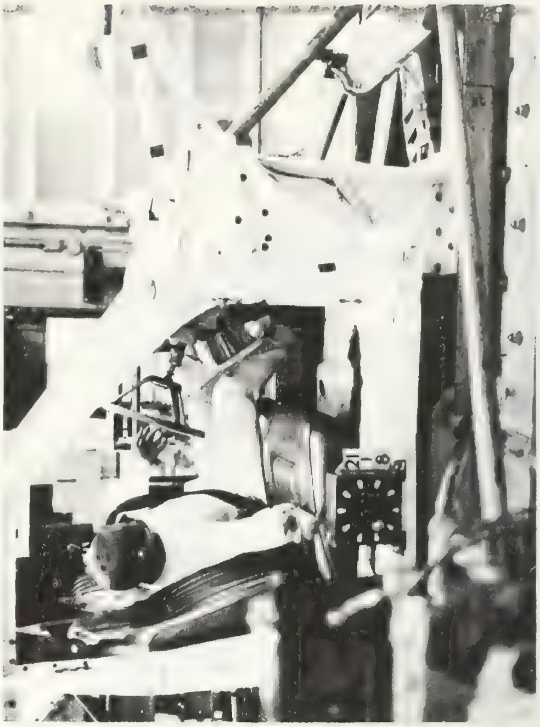

POST TEST

RUN 2118

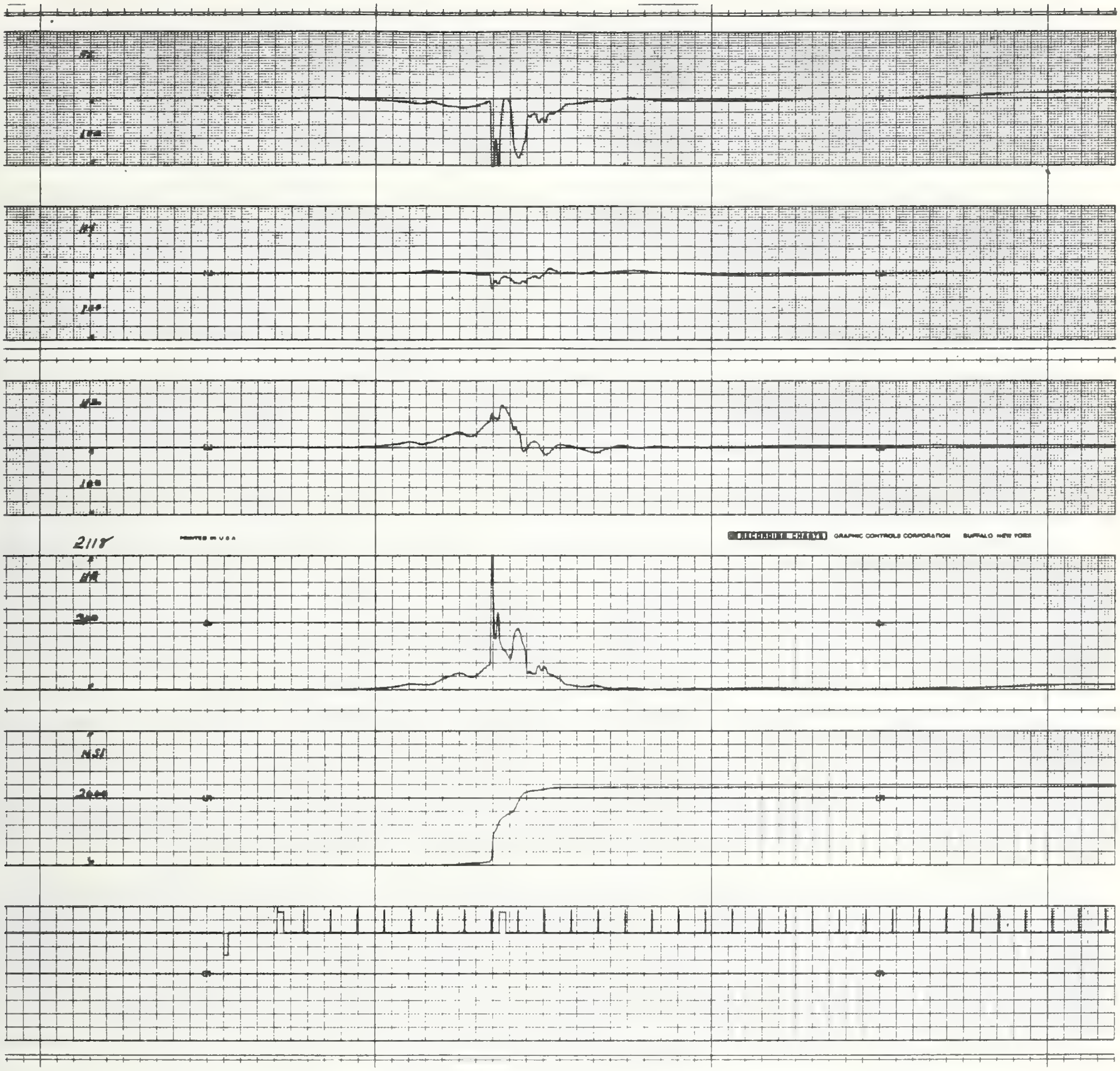




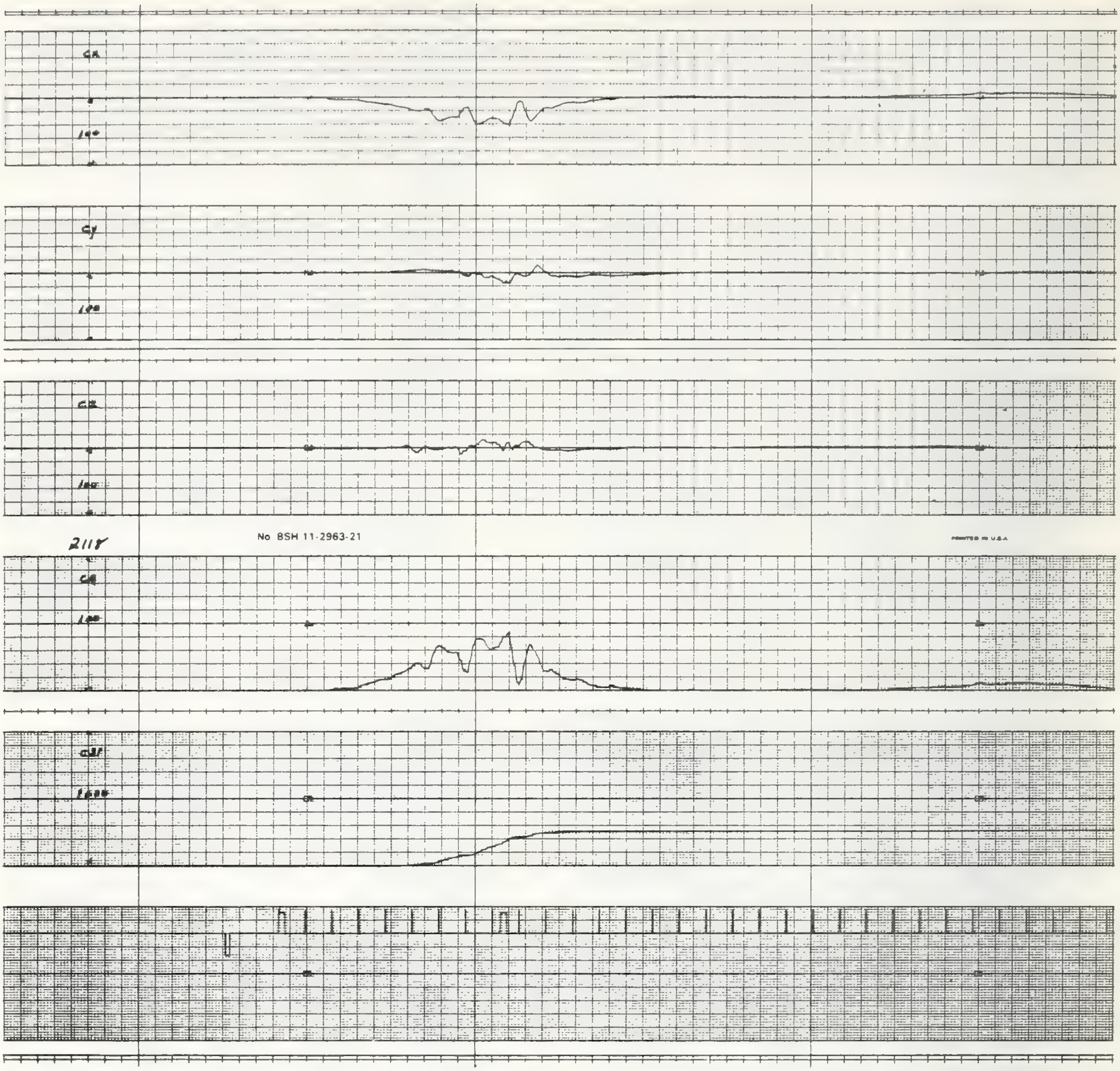
PRETEST



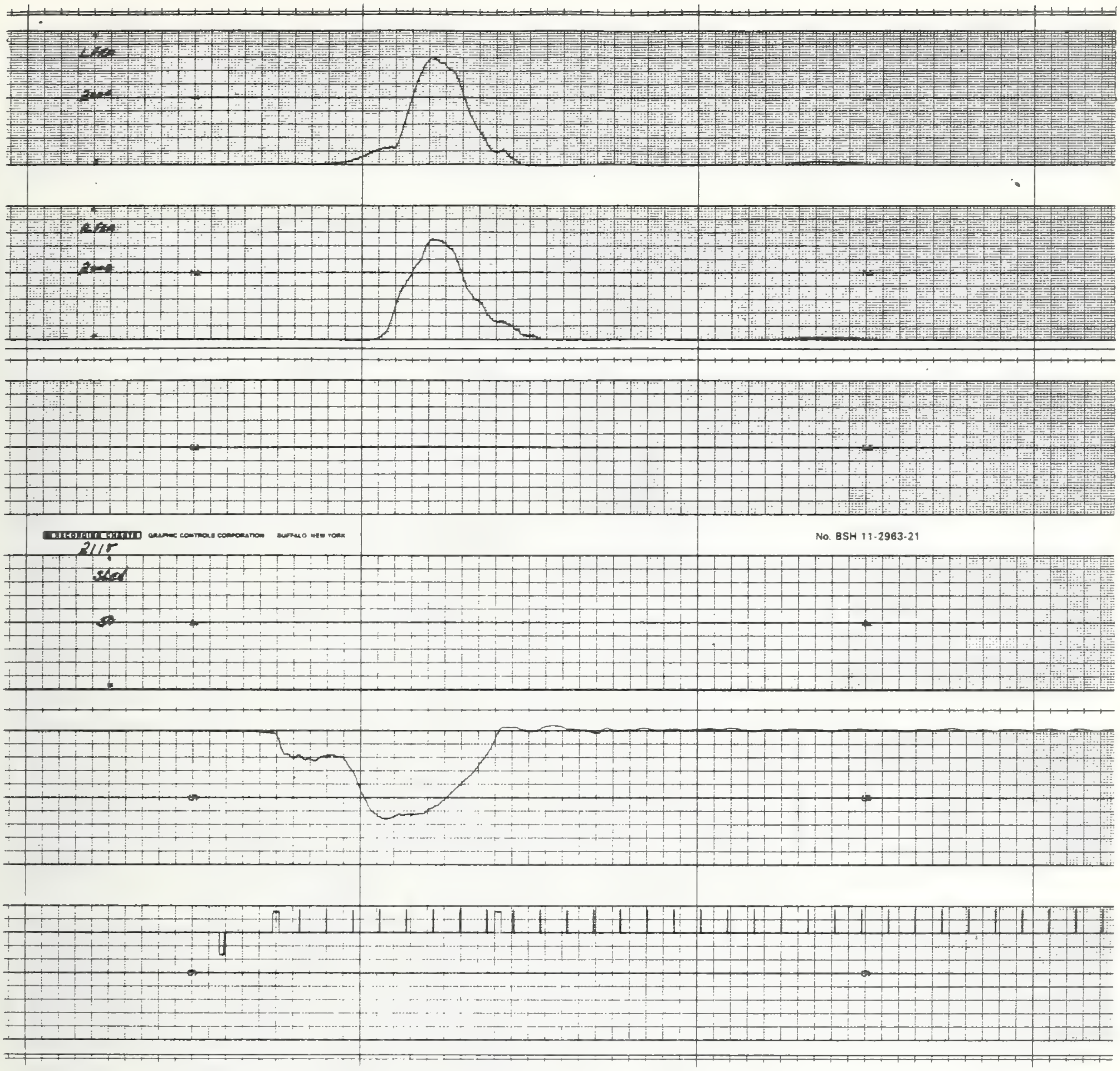
POST TEST
RUN 2118



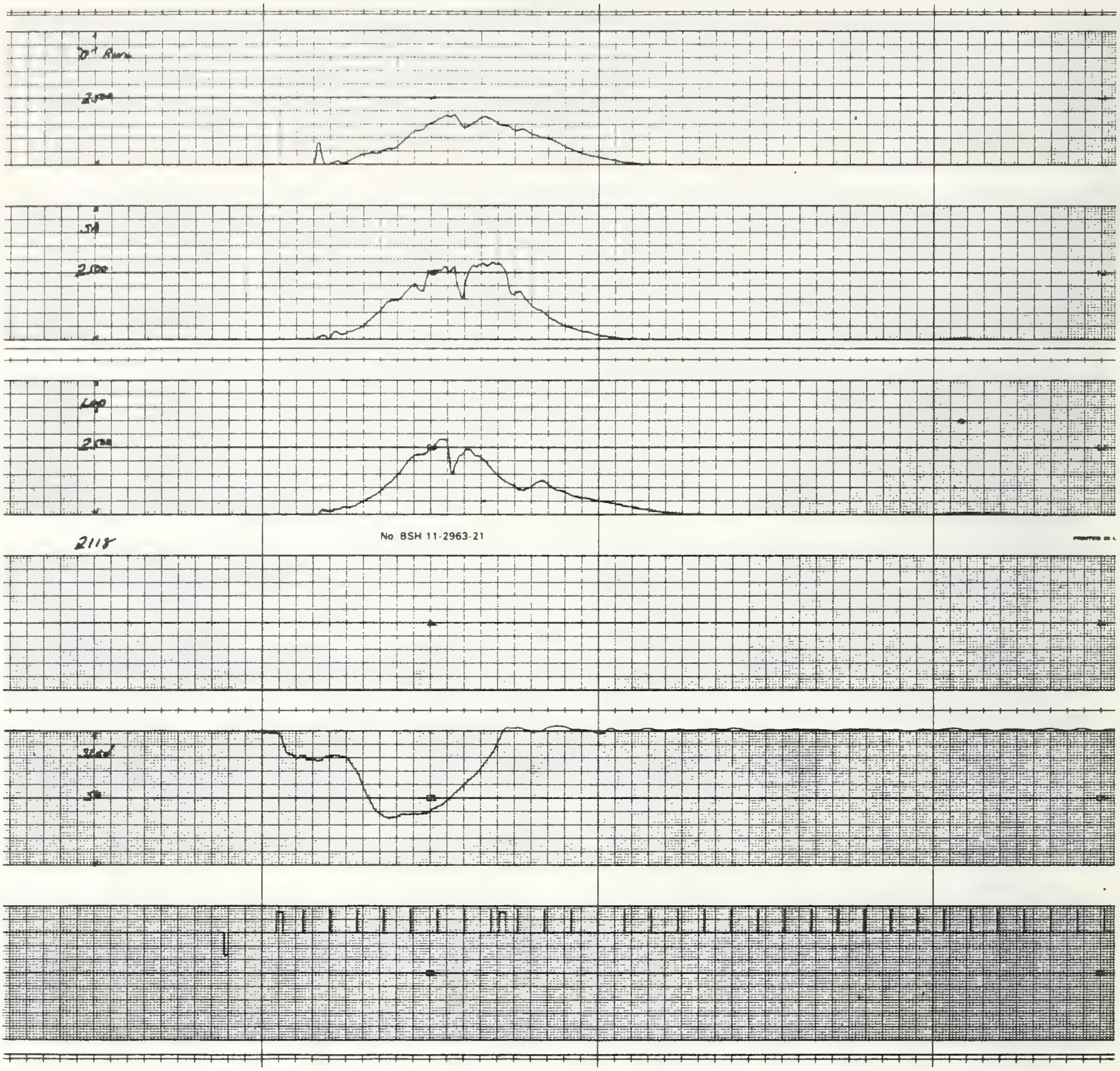
Time = 10 ms/division



Time = 10 ms/division



Time = 10 ms/division

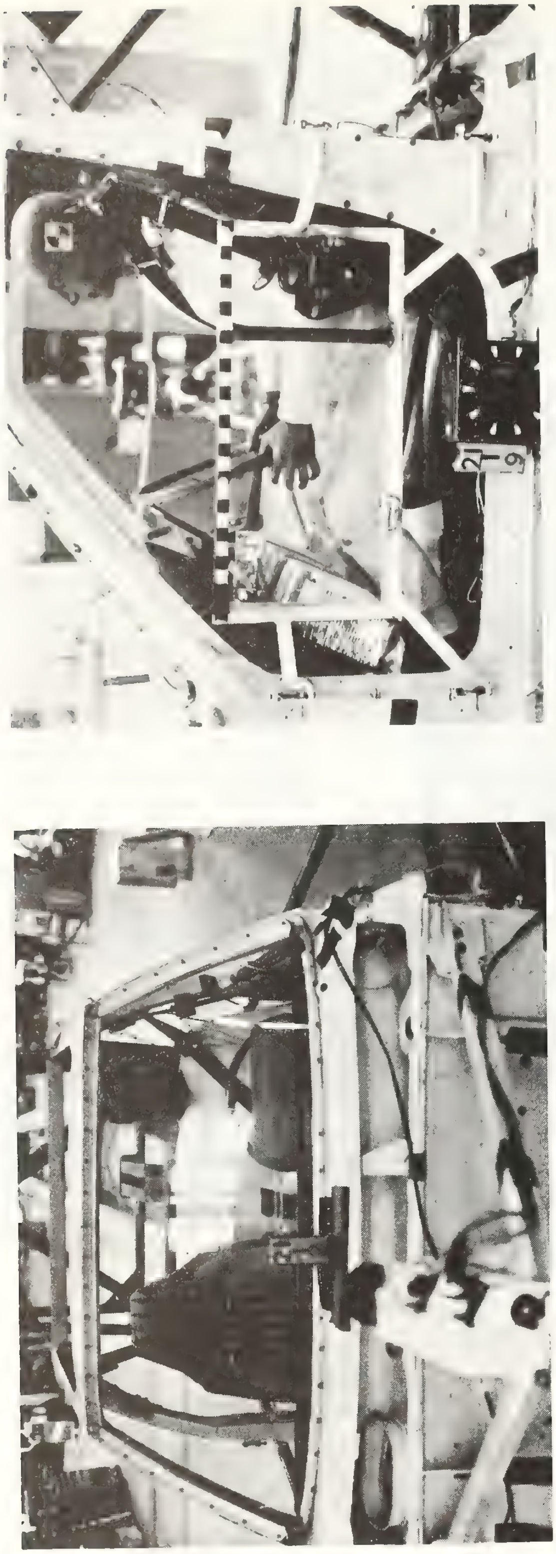


Time = 10 ms/division

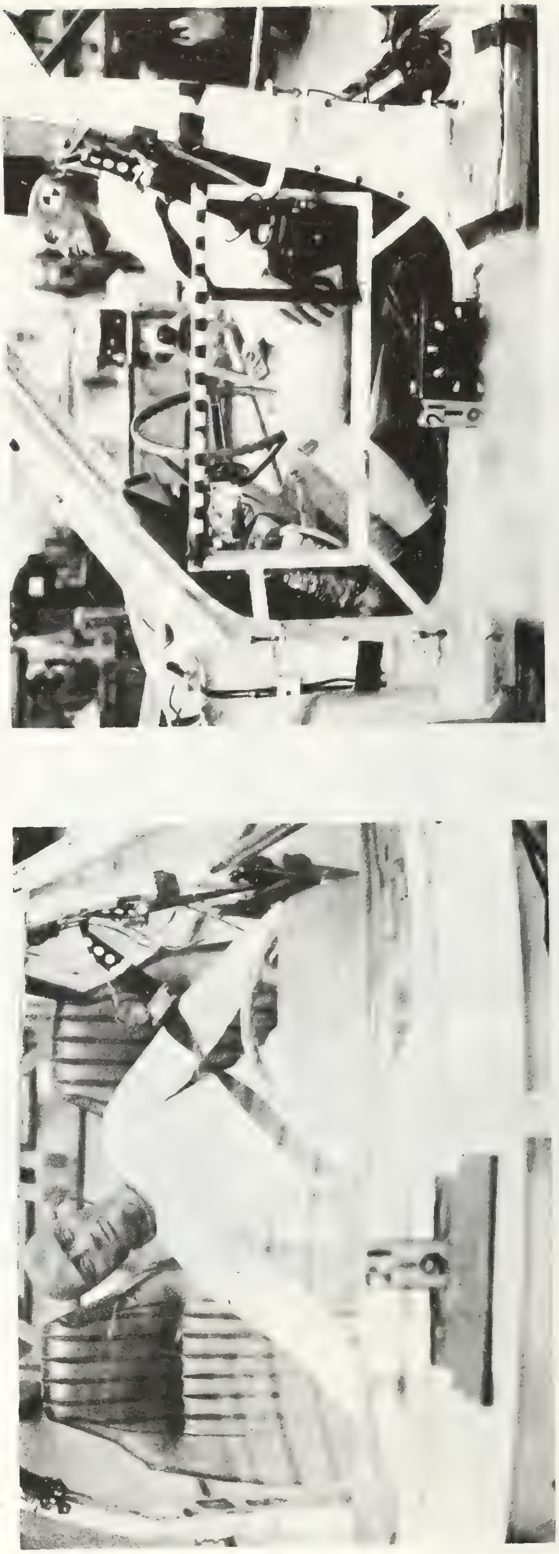
1 2 3 4

5 7 8 6

RUN 2119 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

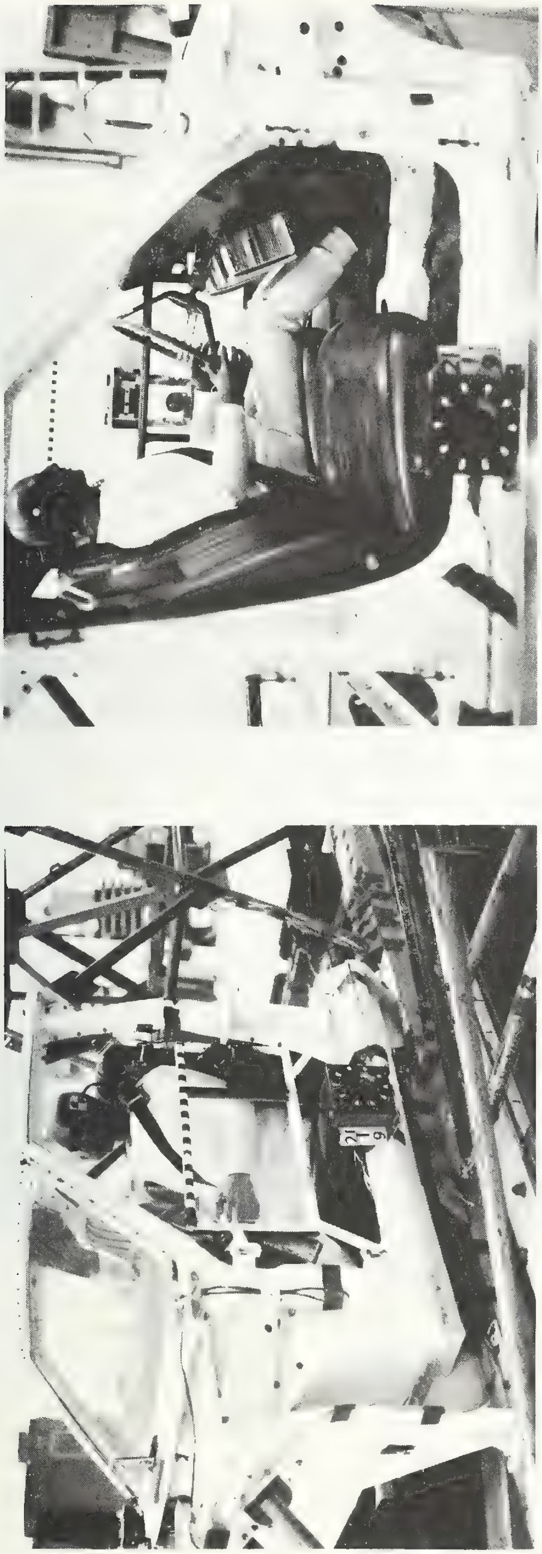


PRETEST

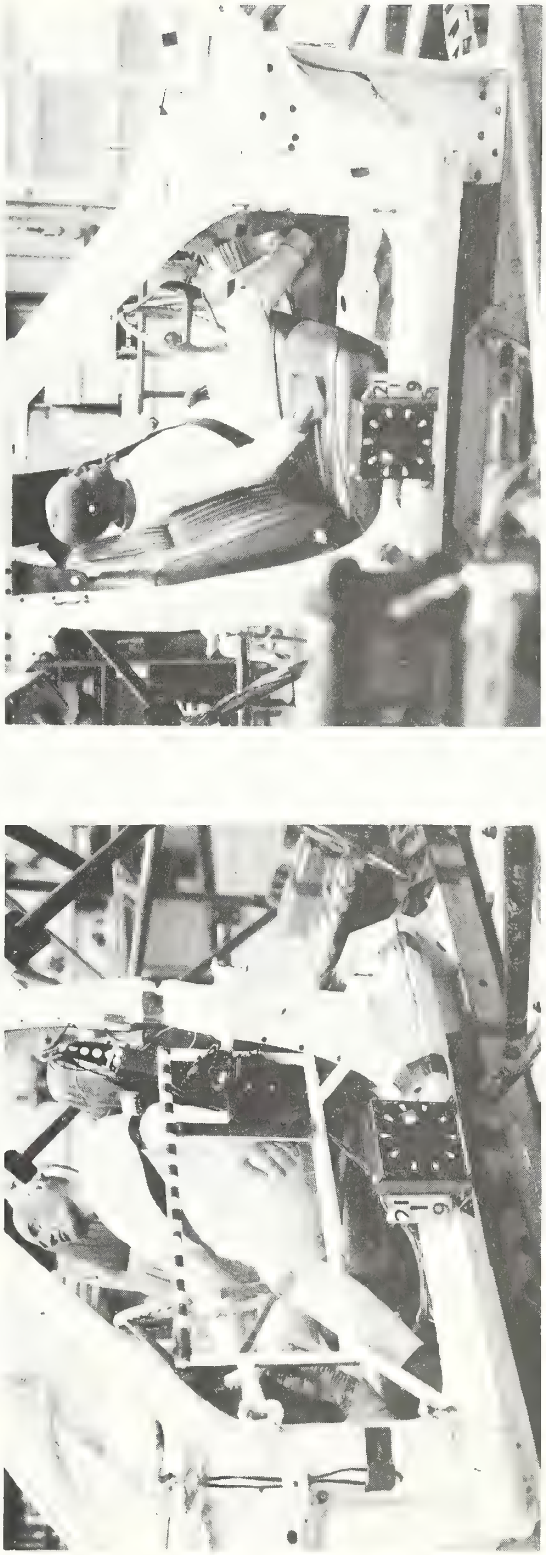


POST TEST

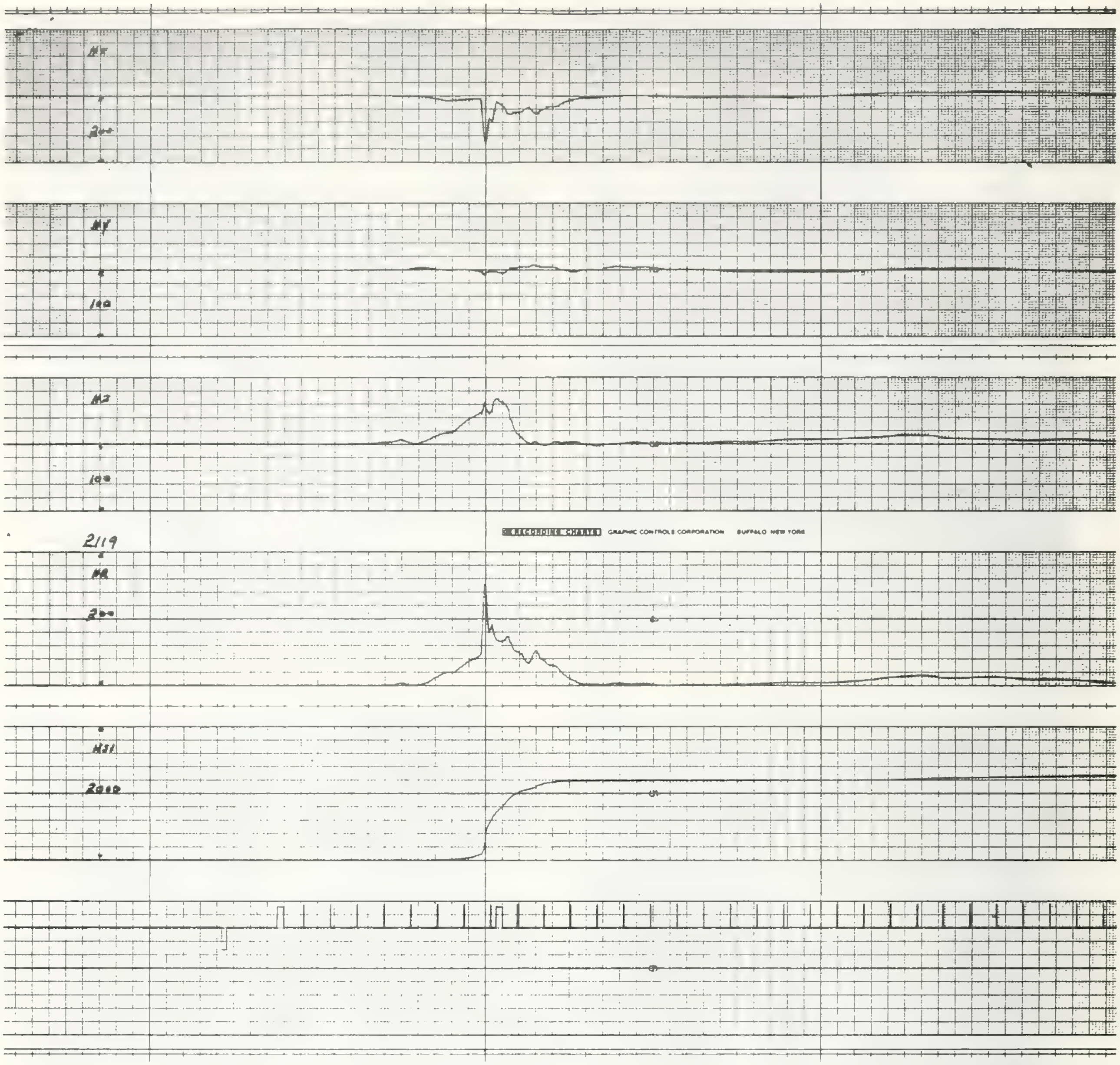
RUN 2119



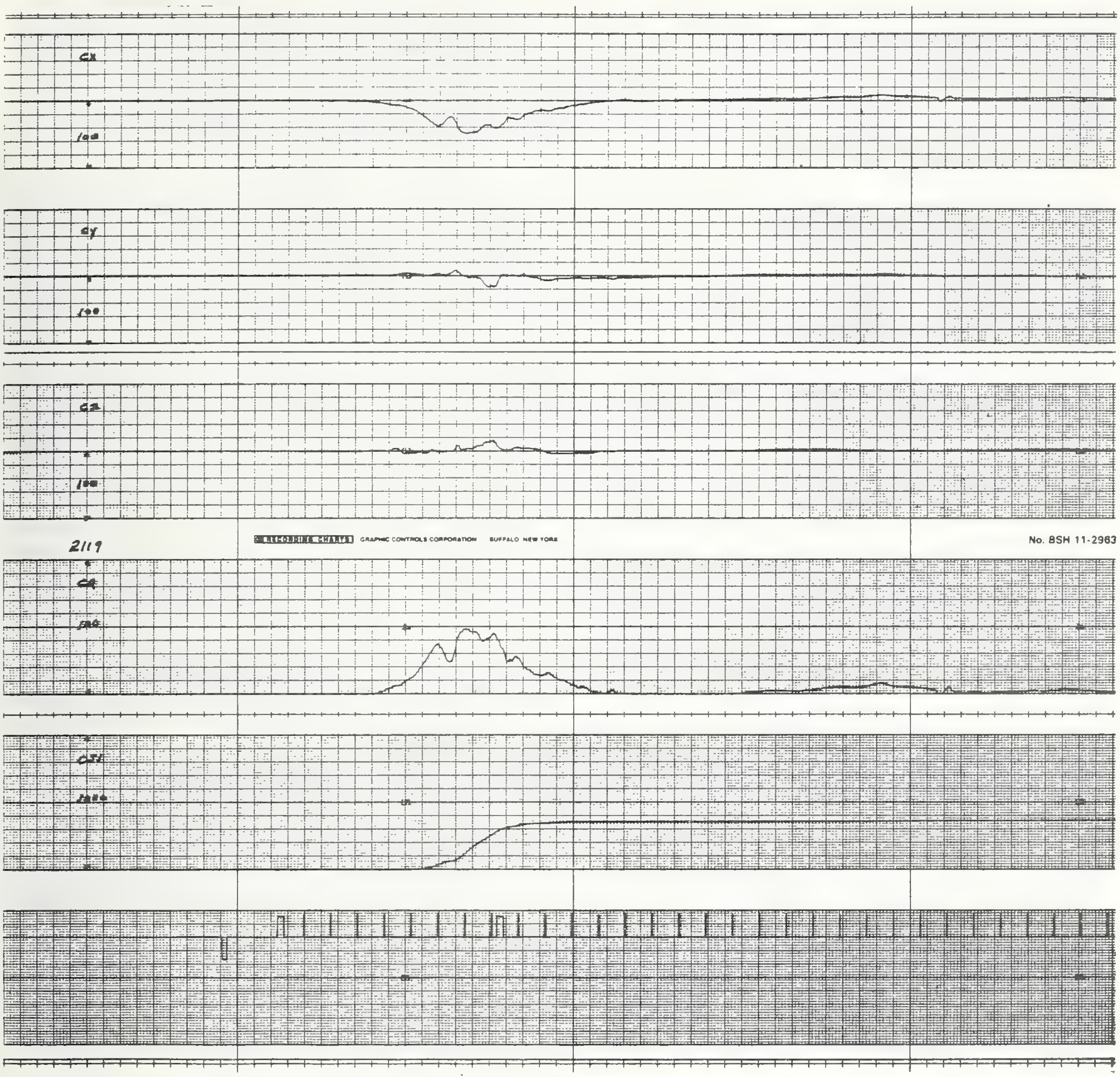
PRETEST



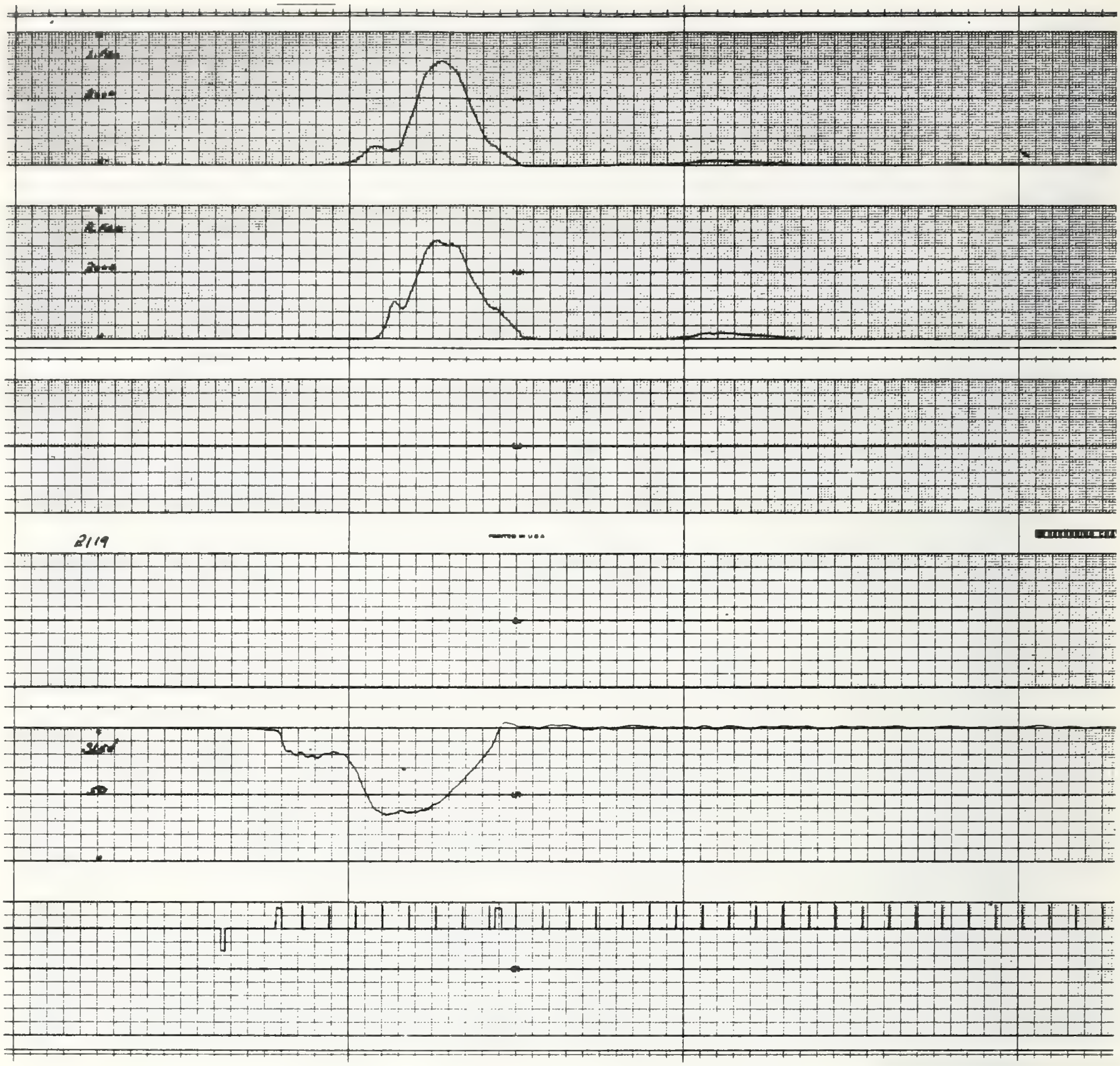
POST TEST
RUN 2119



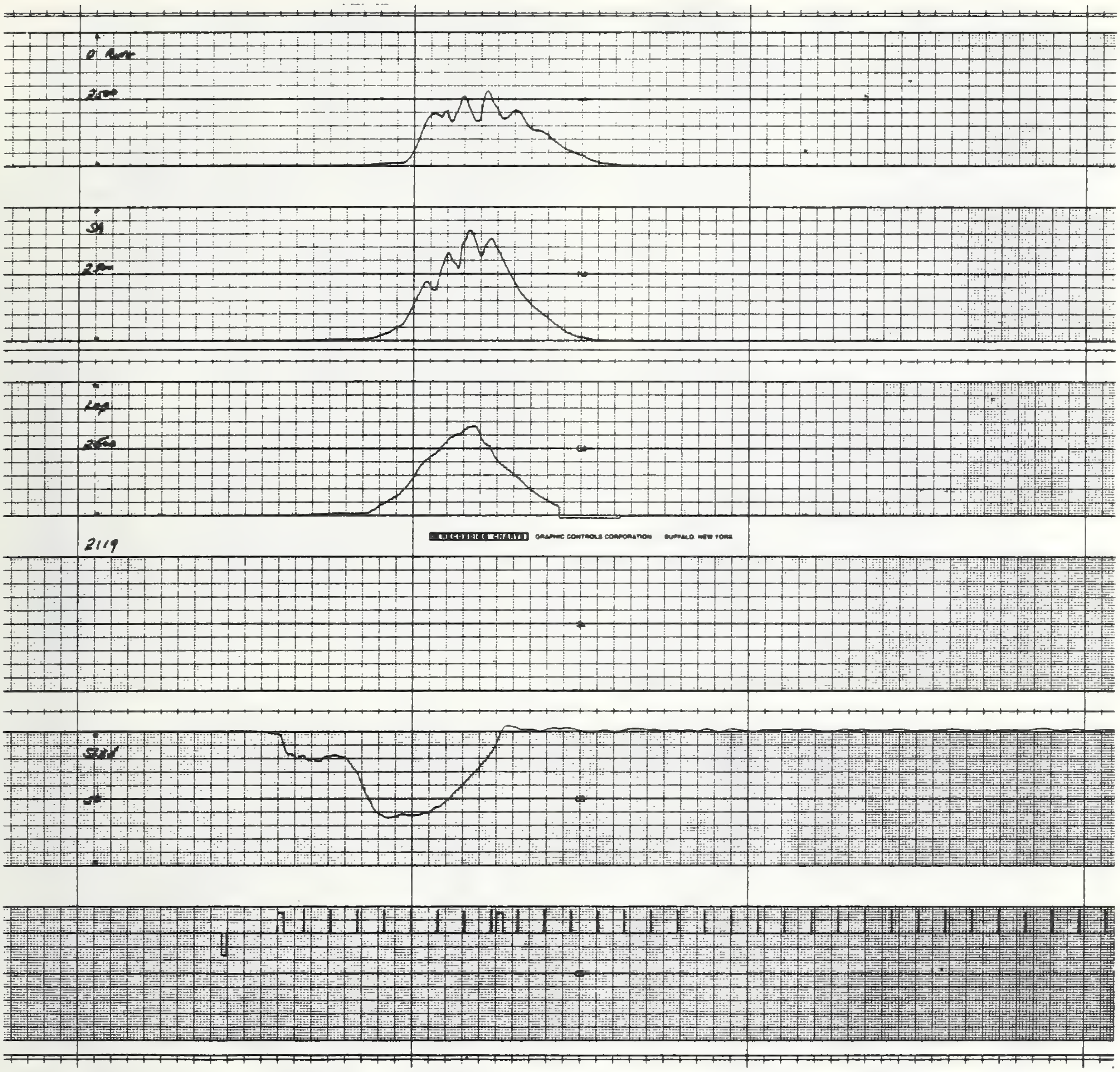
Time = 10 ms/division



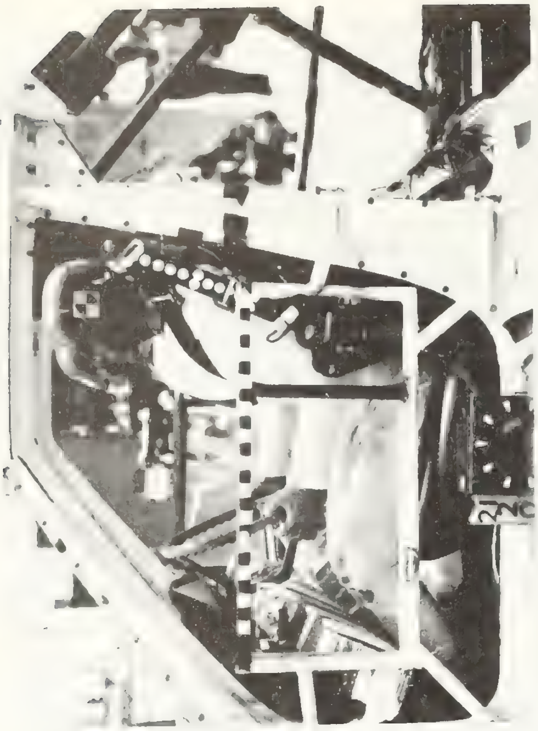
Time = 10 ms/division



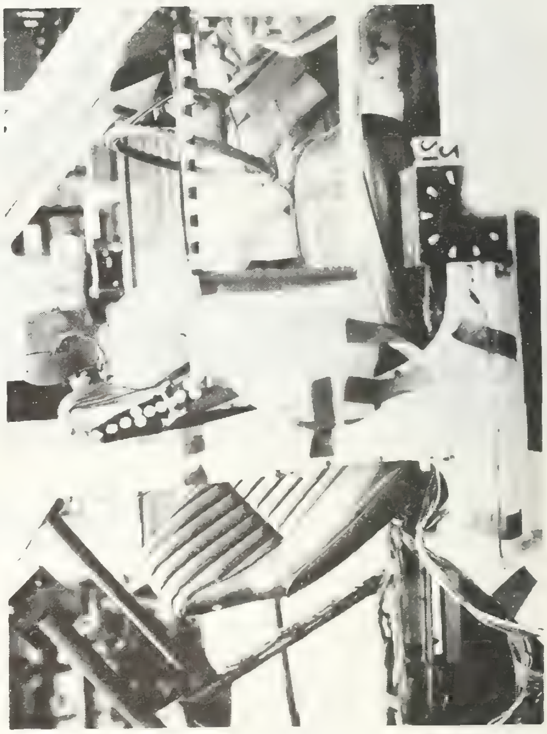
Time = 10 ms/division



Time = 10 ms/division

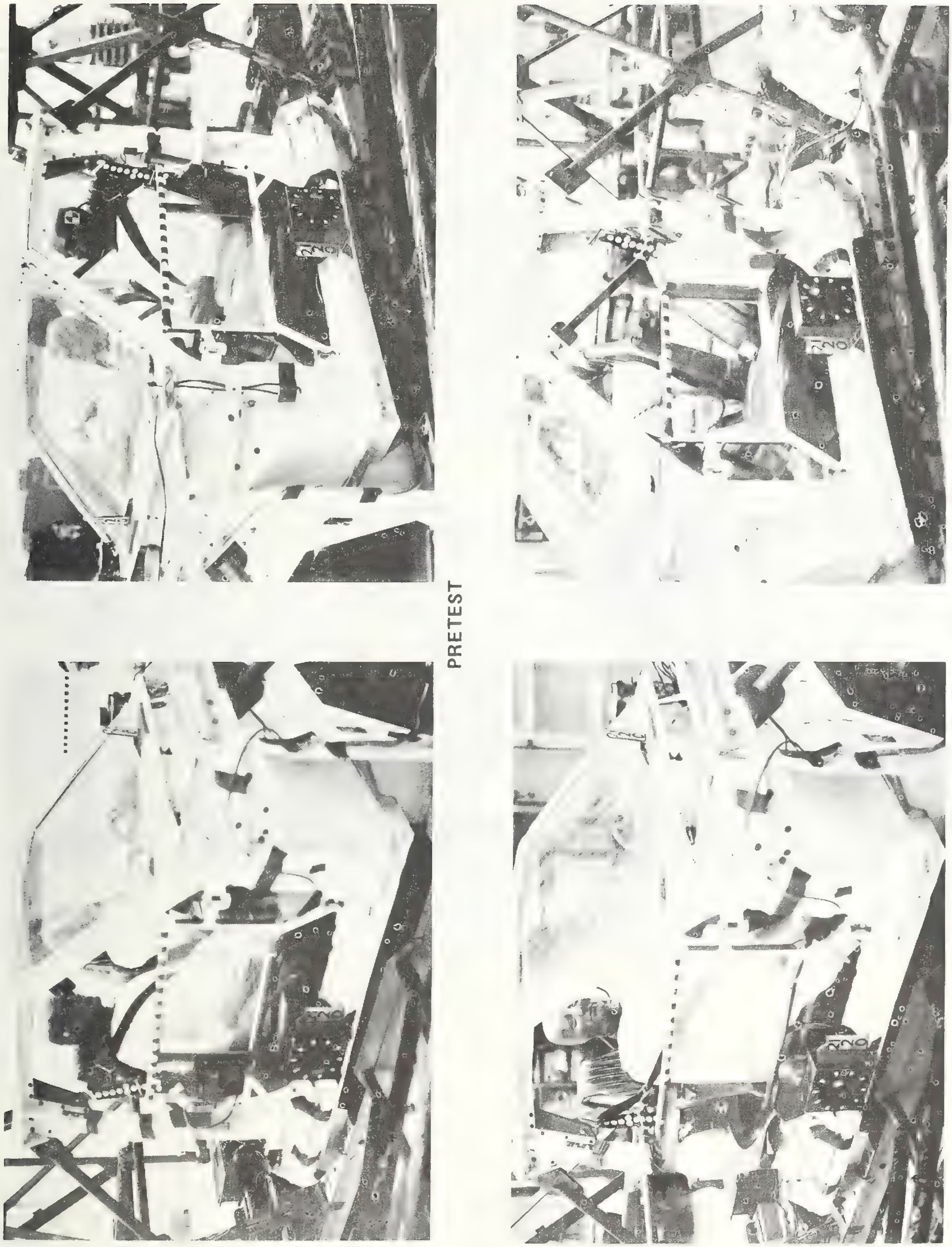


PRETEST



POST TEST

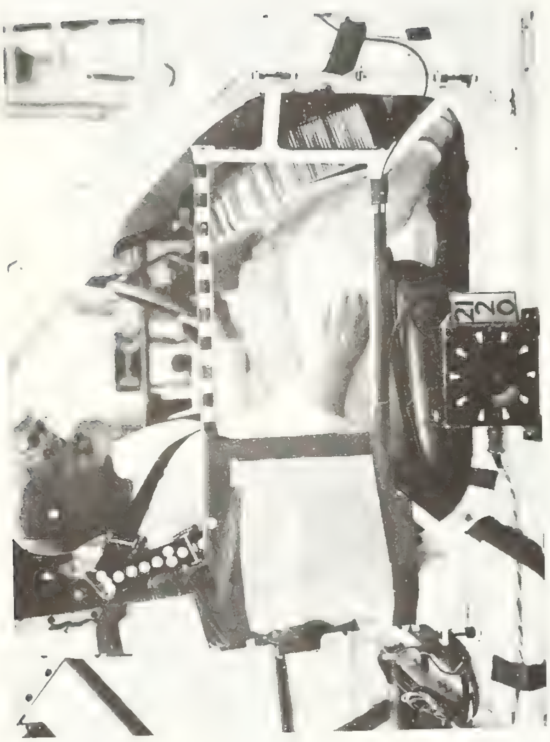
RUN 2120



PRETEST

POST TEST

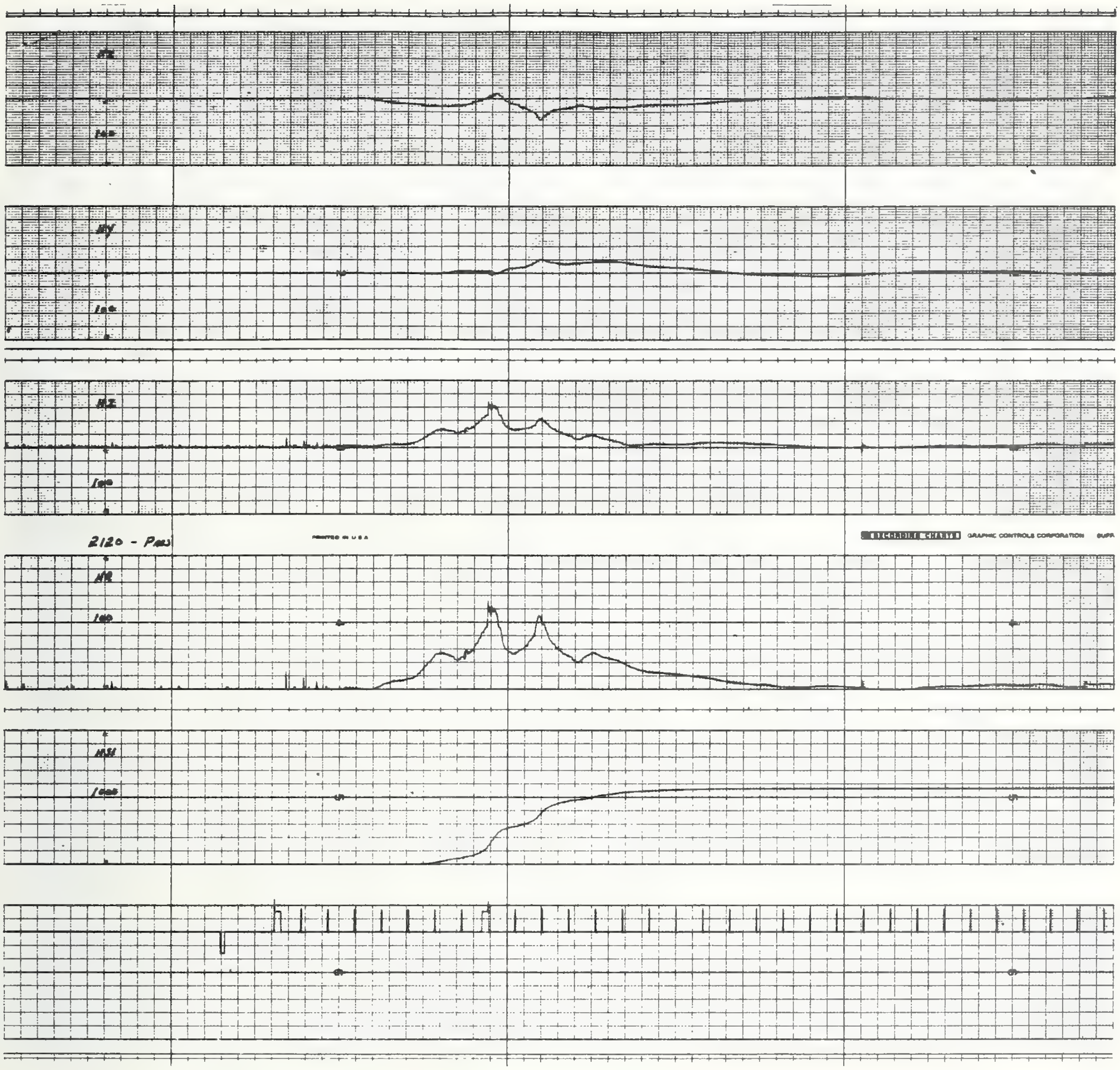
RUN 2120



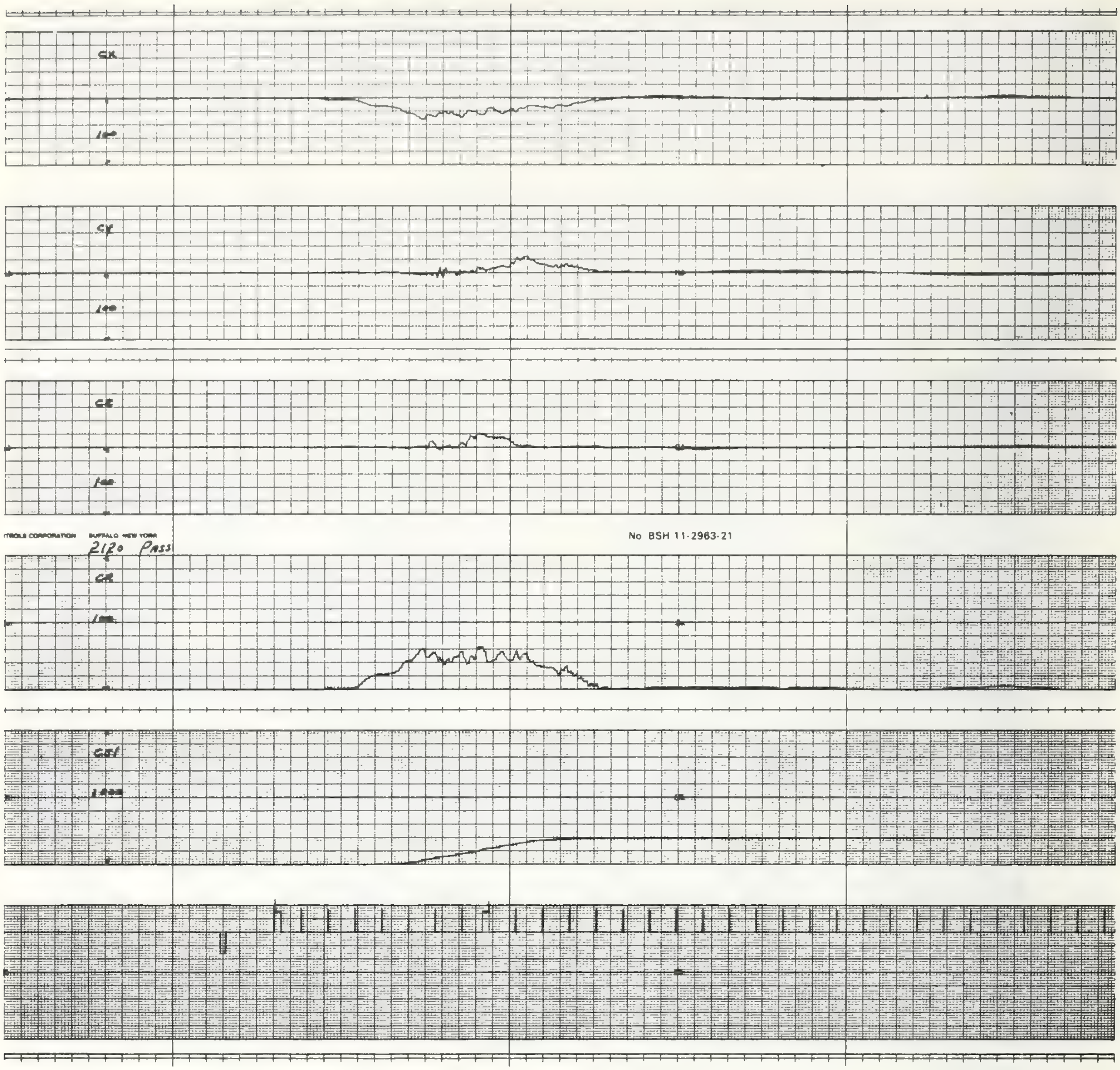
PRETEST

POST TEST

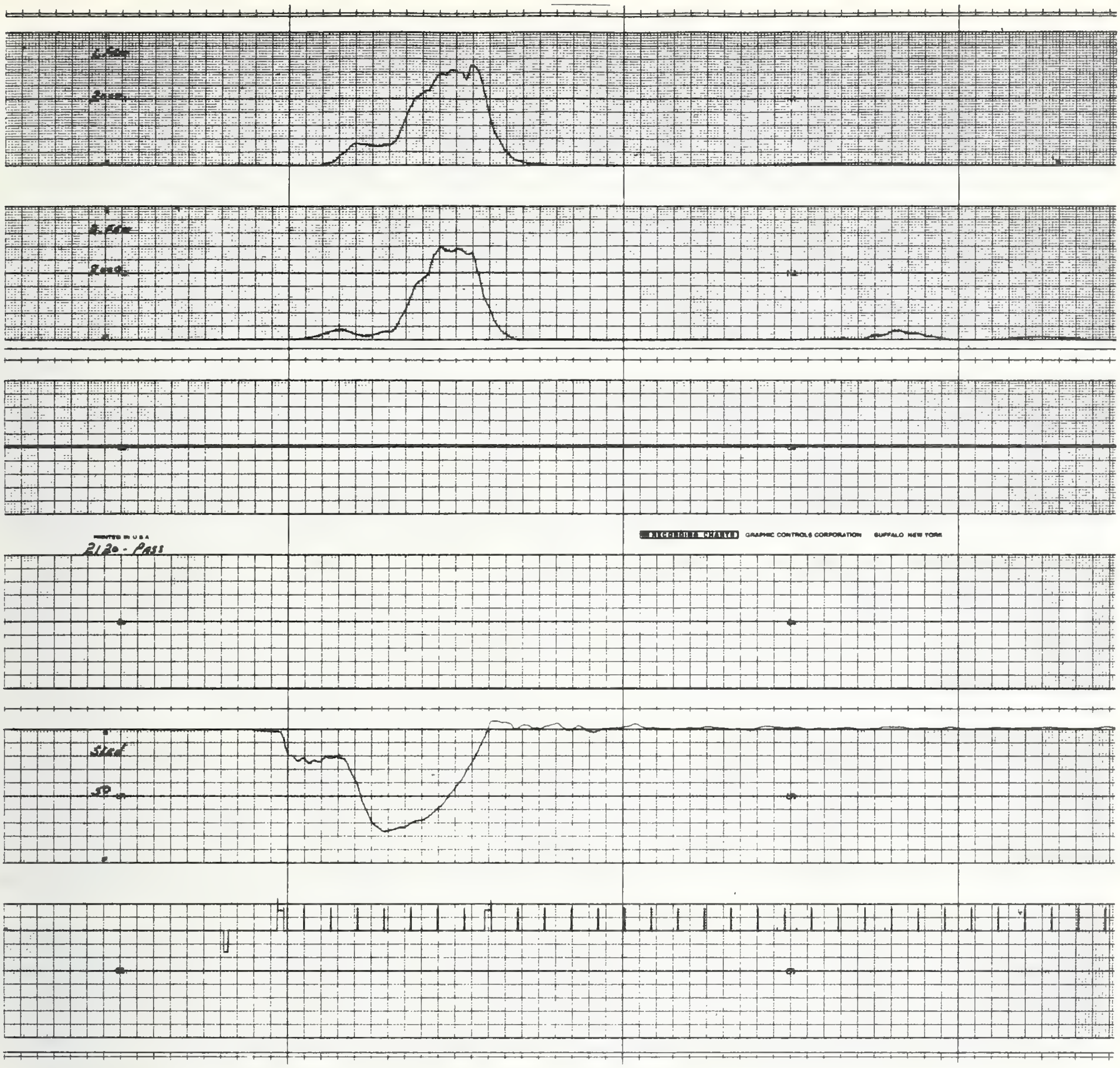
RUN 2120



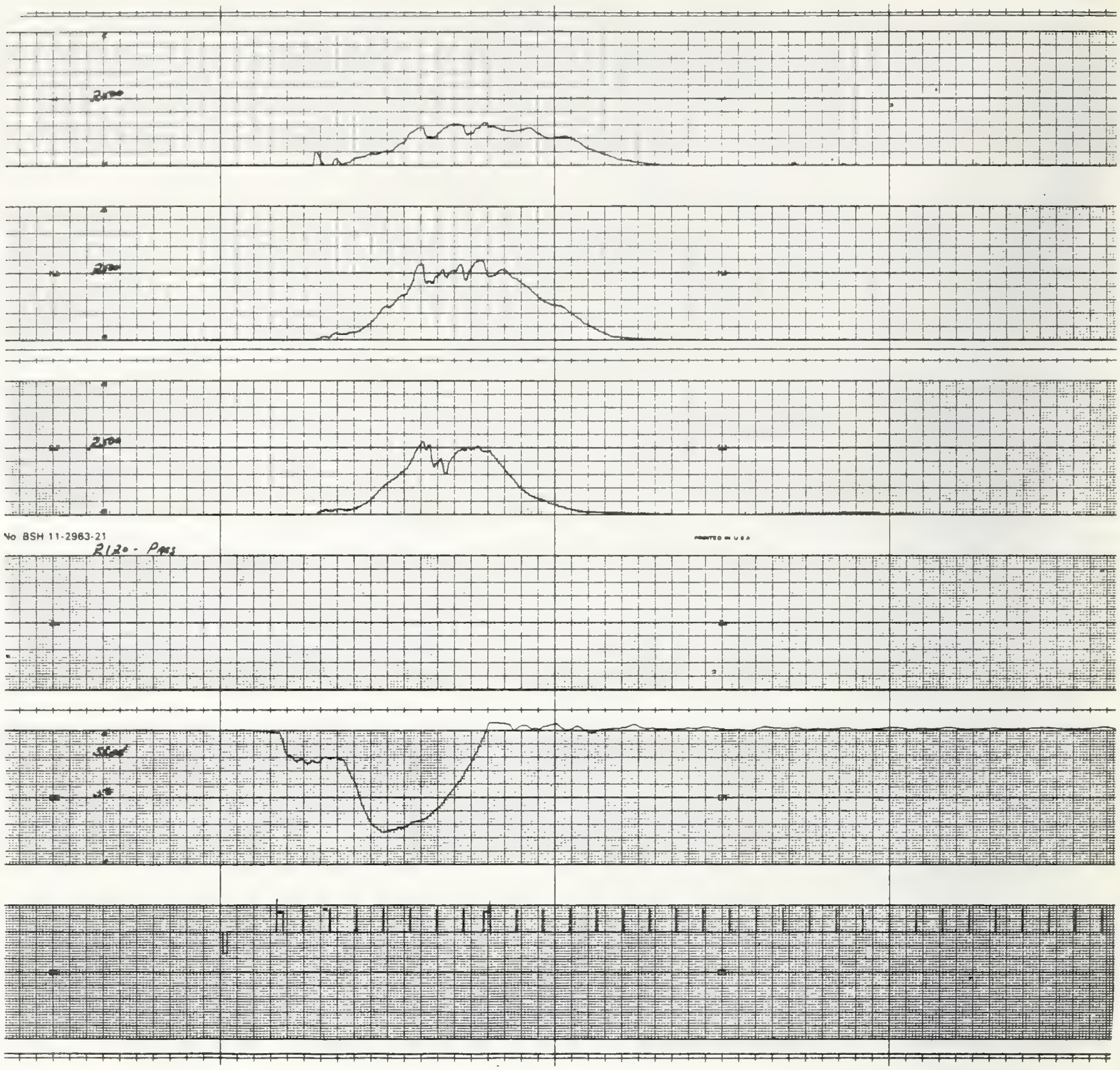
Time = 10 ms/division



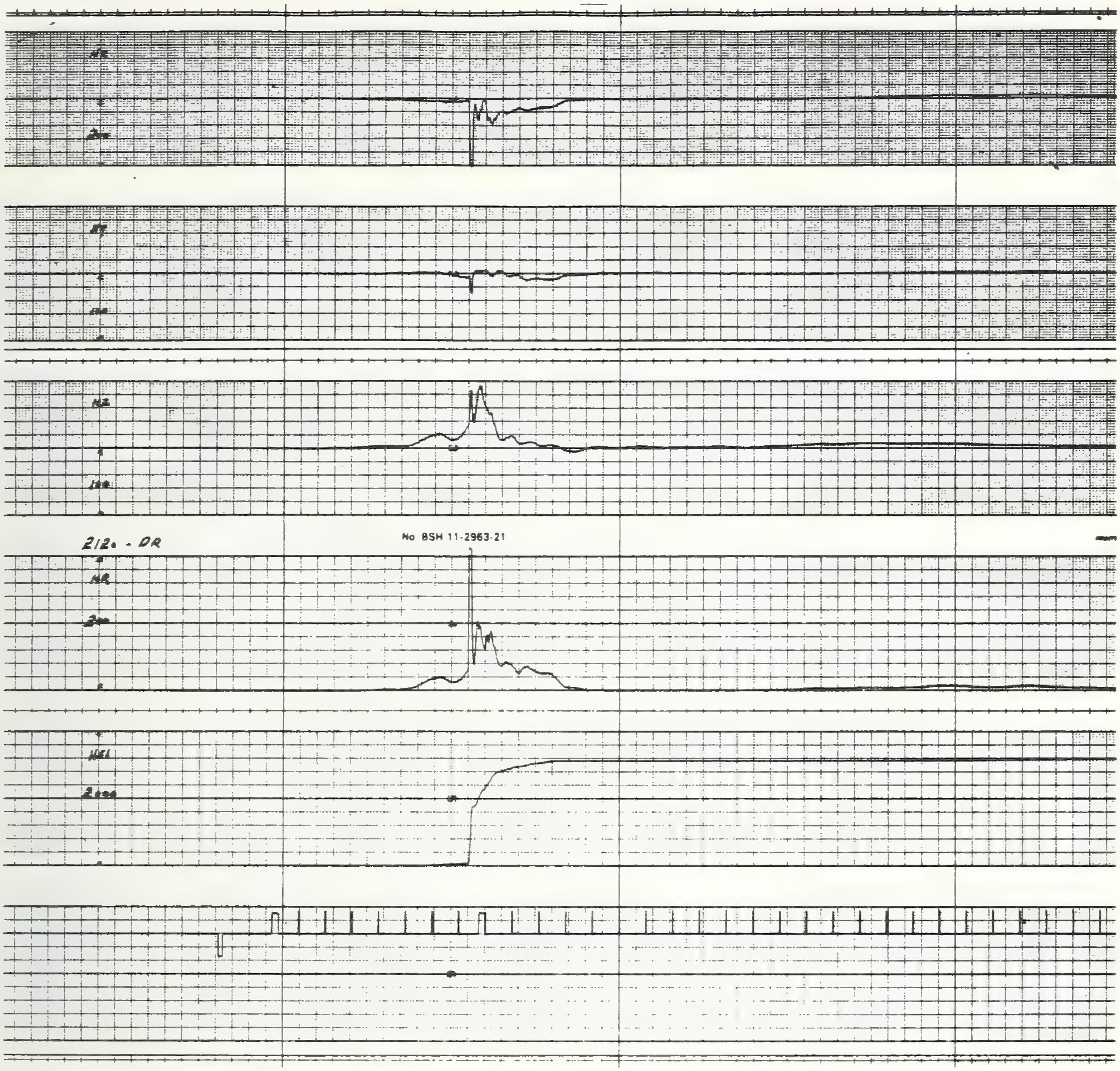
Time = 10 ms/division



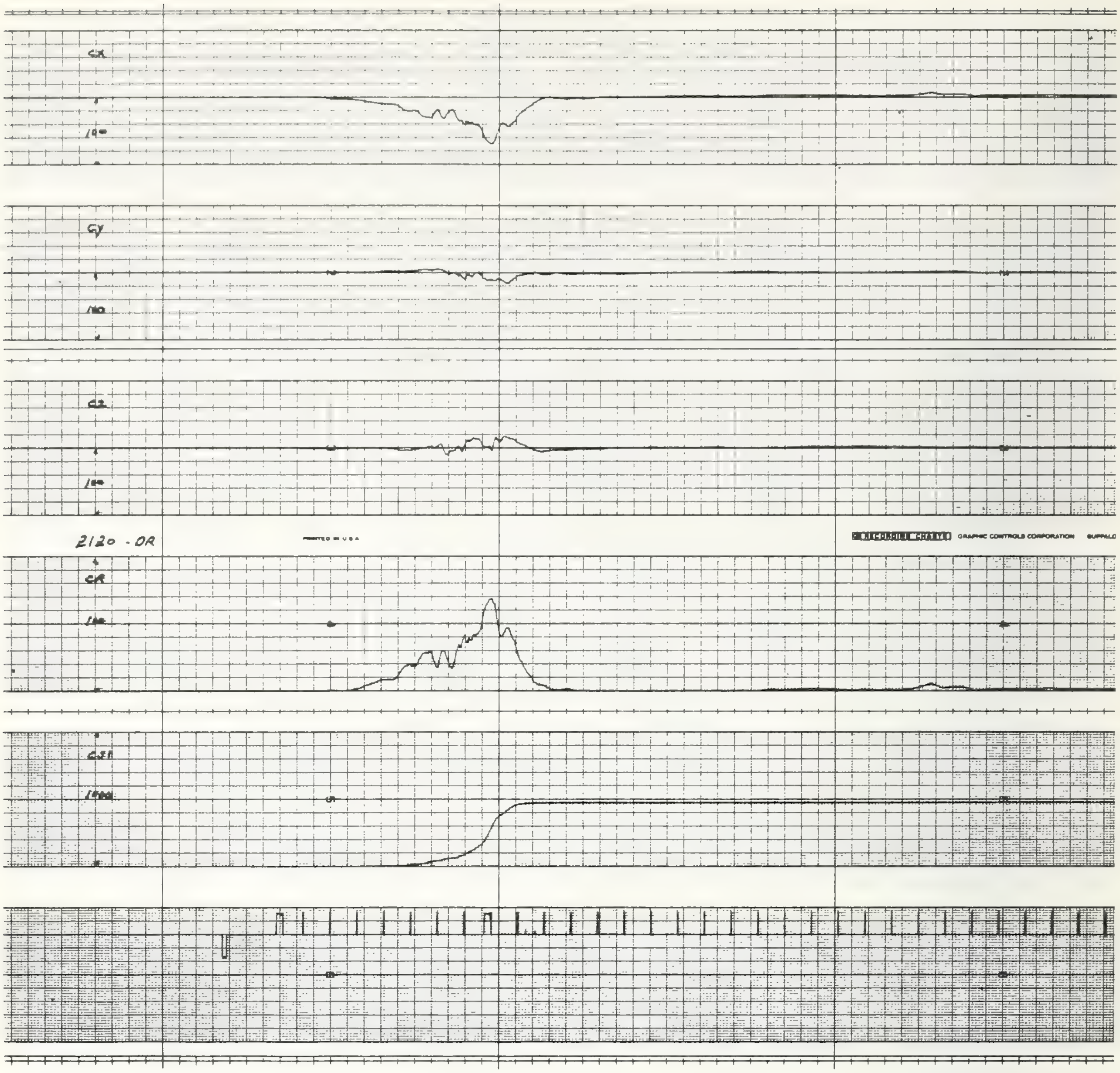
Time = 10 ms/division



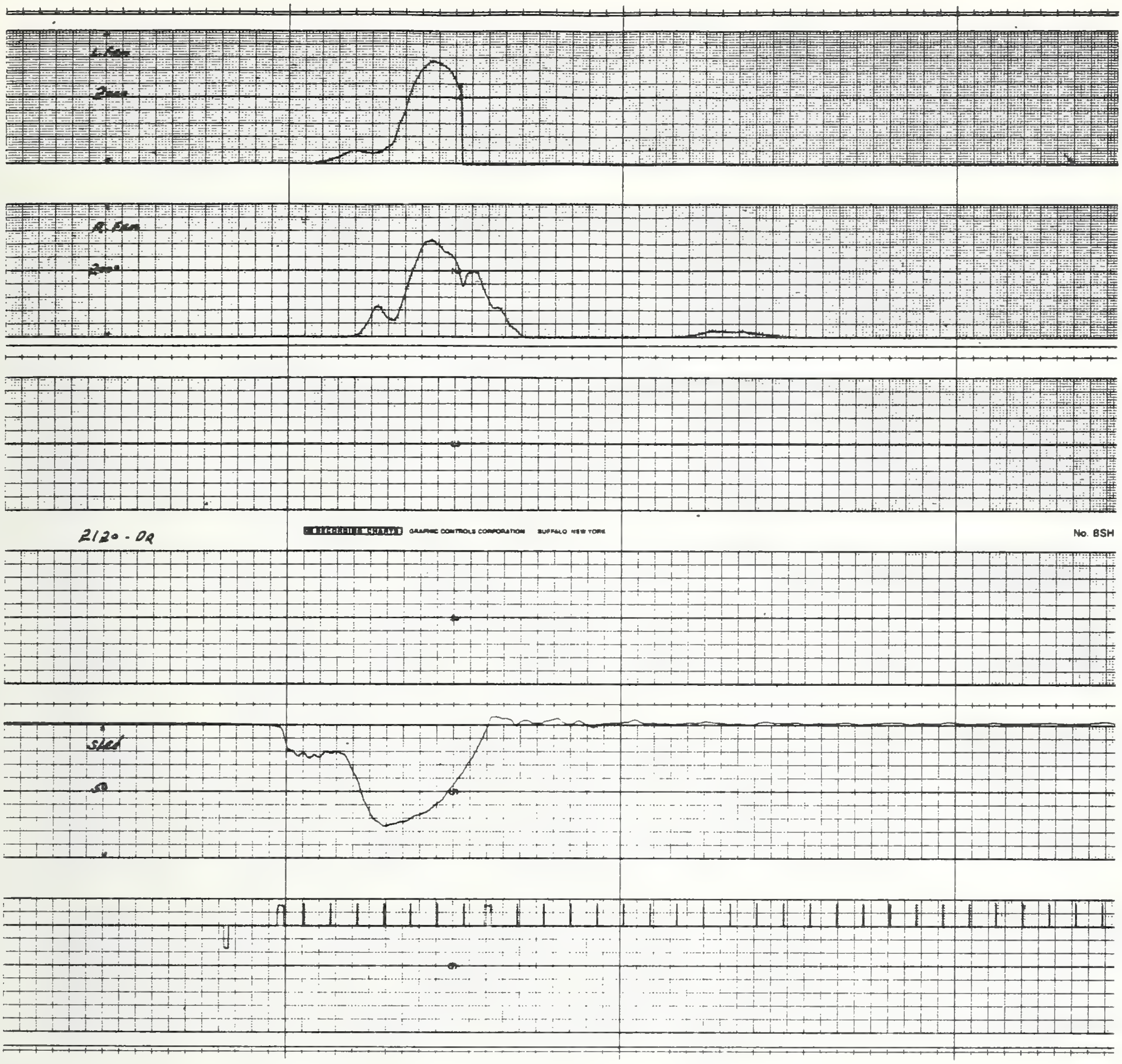
Time = 10 ms/division



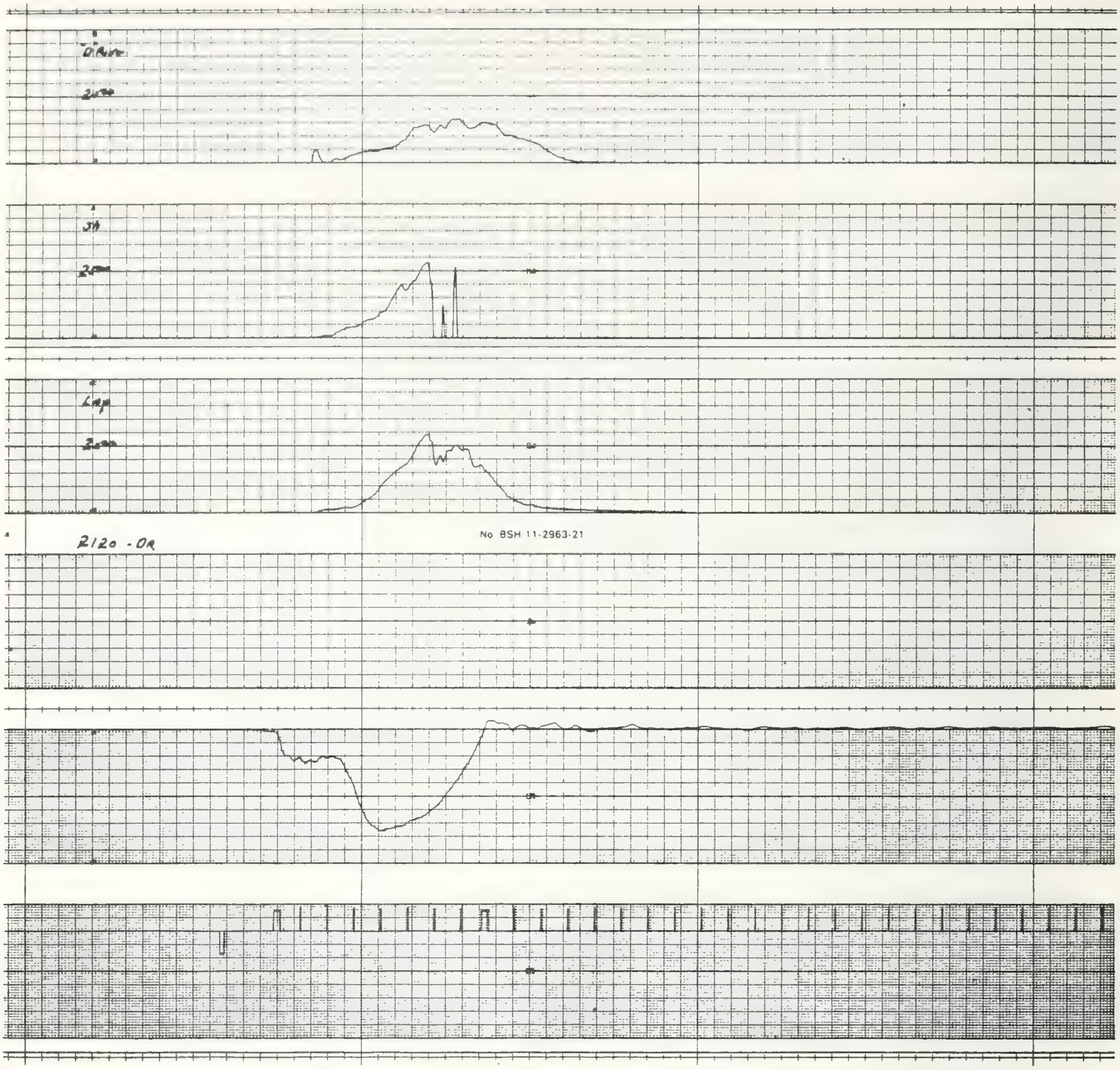
Time = 10 ms/division



Time = 10 ms/division

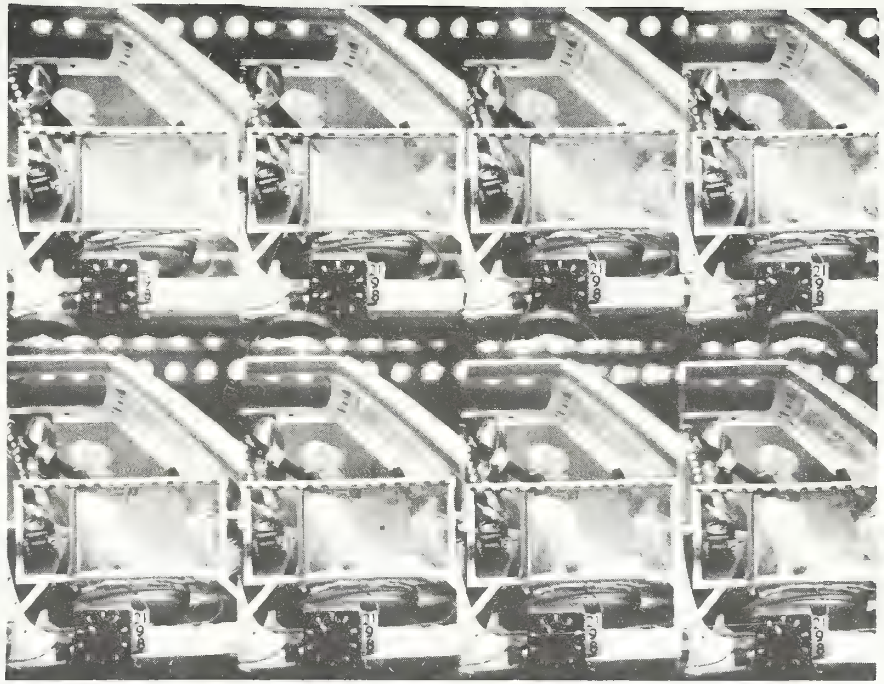


Time = 10 ms/division



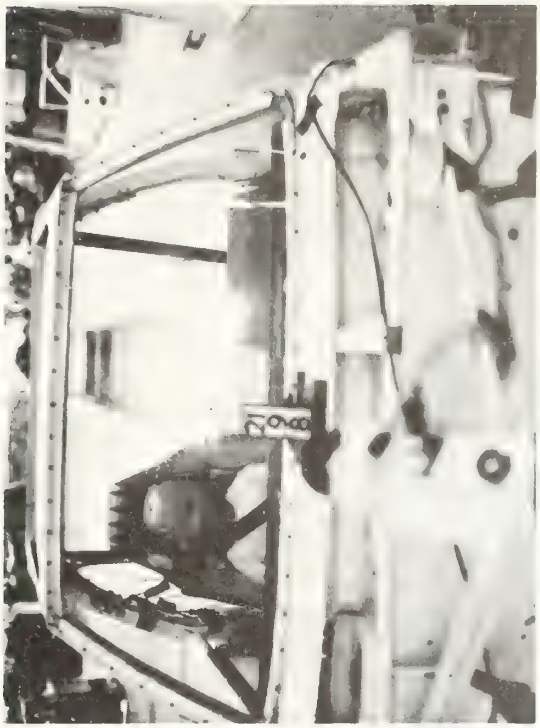
Time = 10 ms/division

1 2 3 4

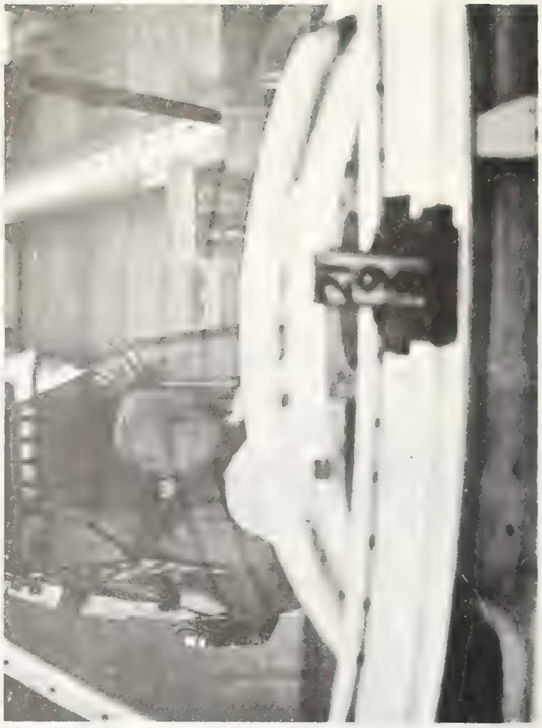


5 6 7 8

RUN 2198 SEQUENCE CAMERA
CLOCK = 10 MS/SEC

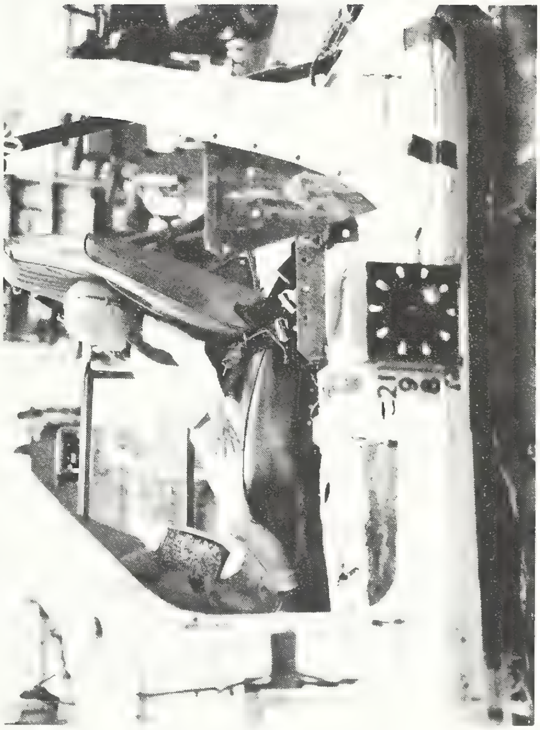


PRE TEST

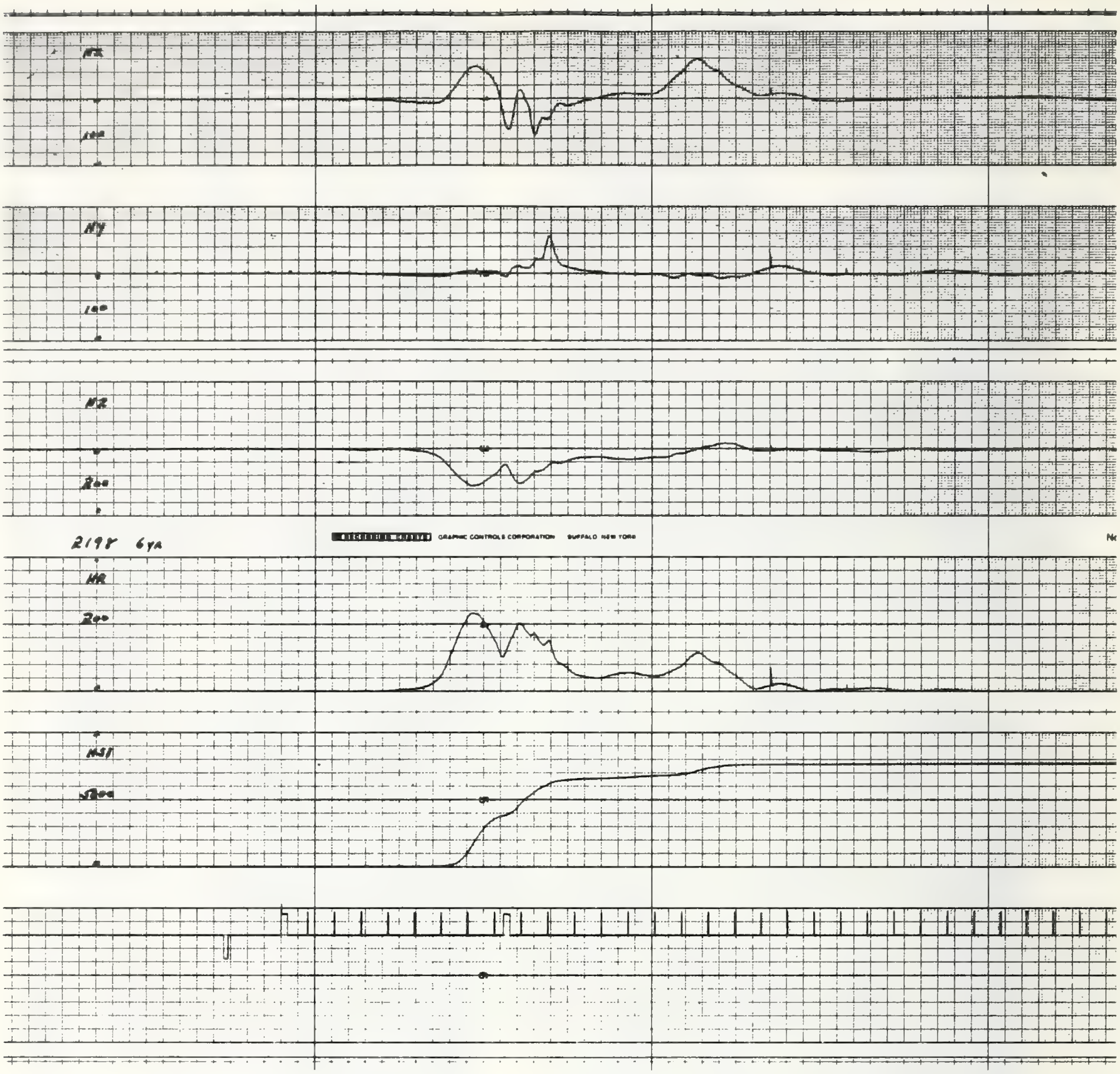


POST TEST
RUN 2198

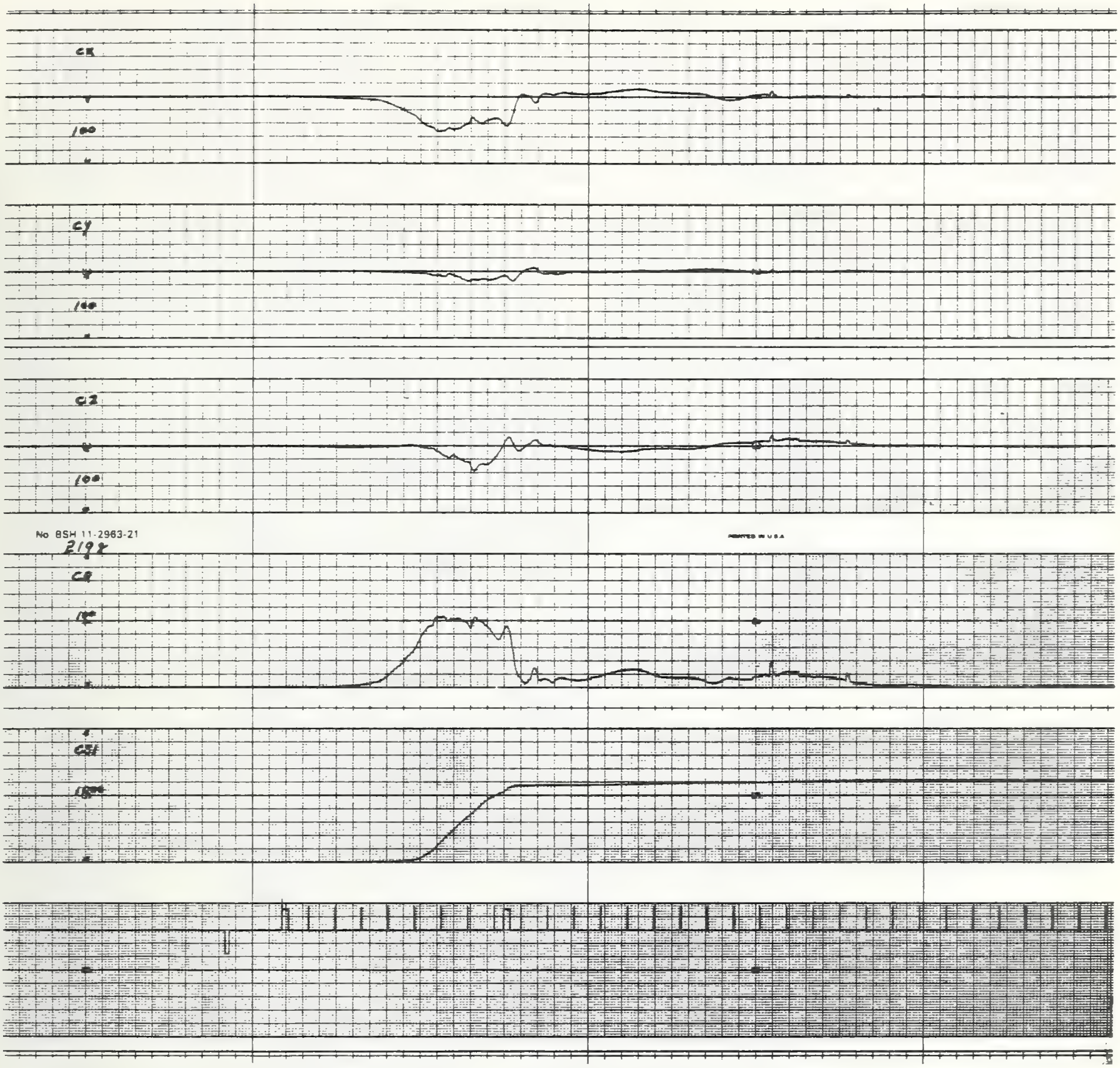
PRETEST



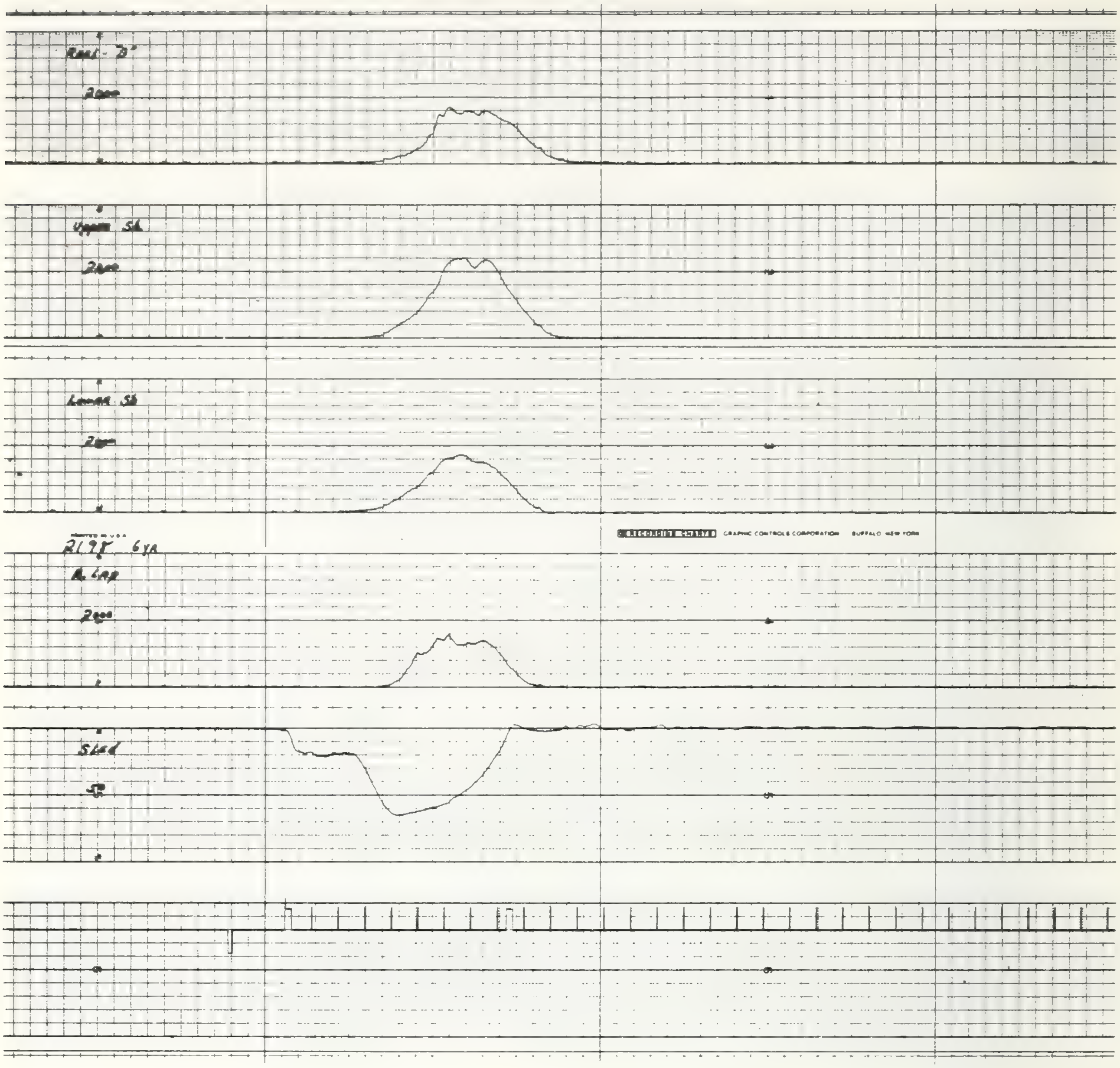
POST TEST
RUN 2198



Time = 10 ms/division



Time = 10 ms/division

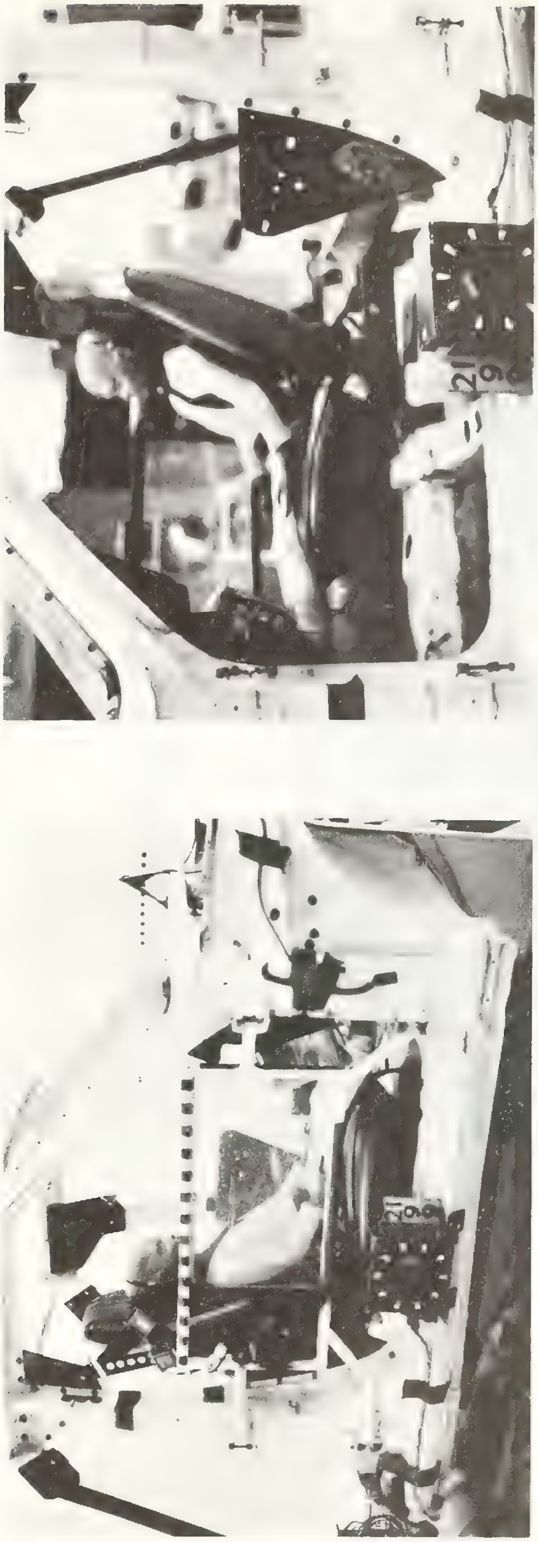


Time = 10 ms/division

1 2 3 4

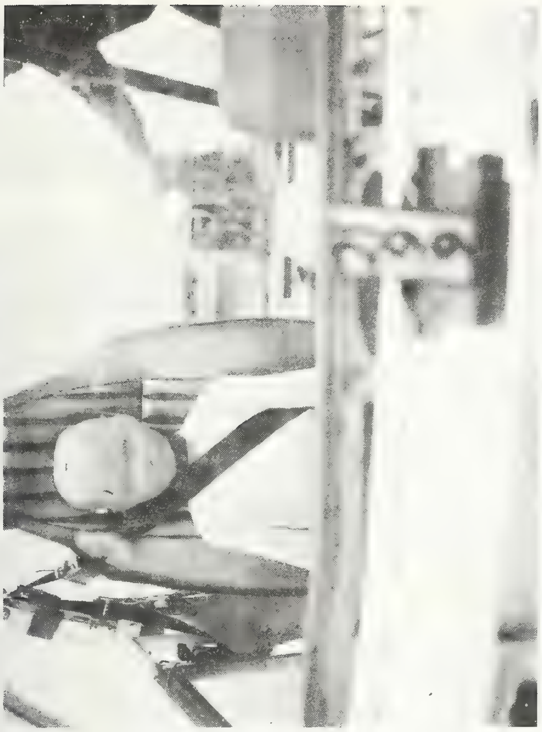
5 6 7 8

RUN 2199 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION



PRETEST

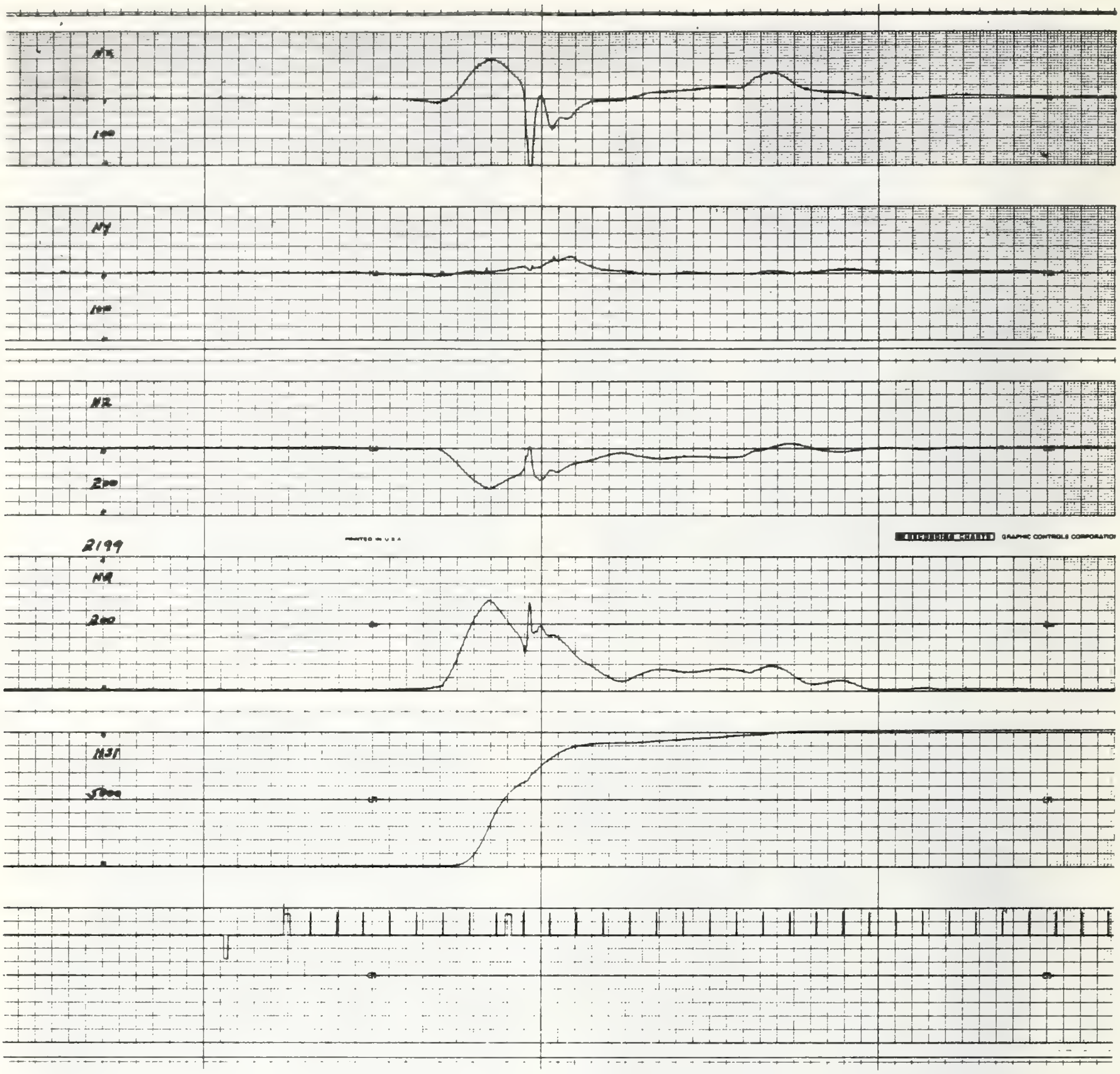
POST TEST
RUN 2199



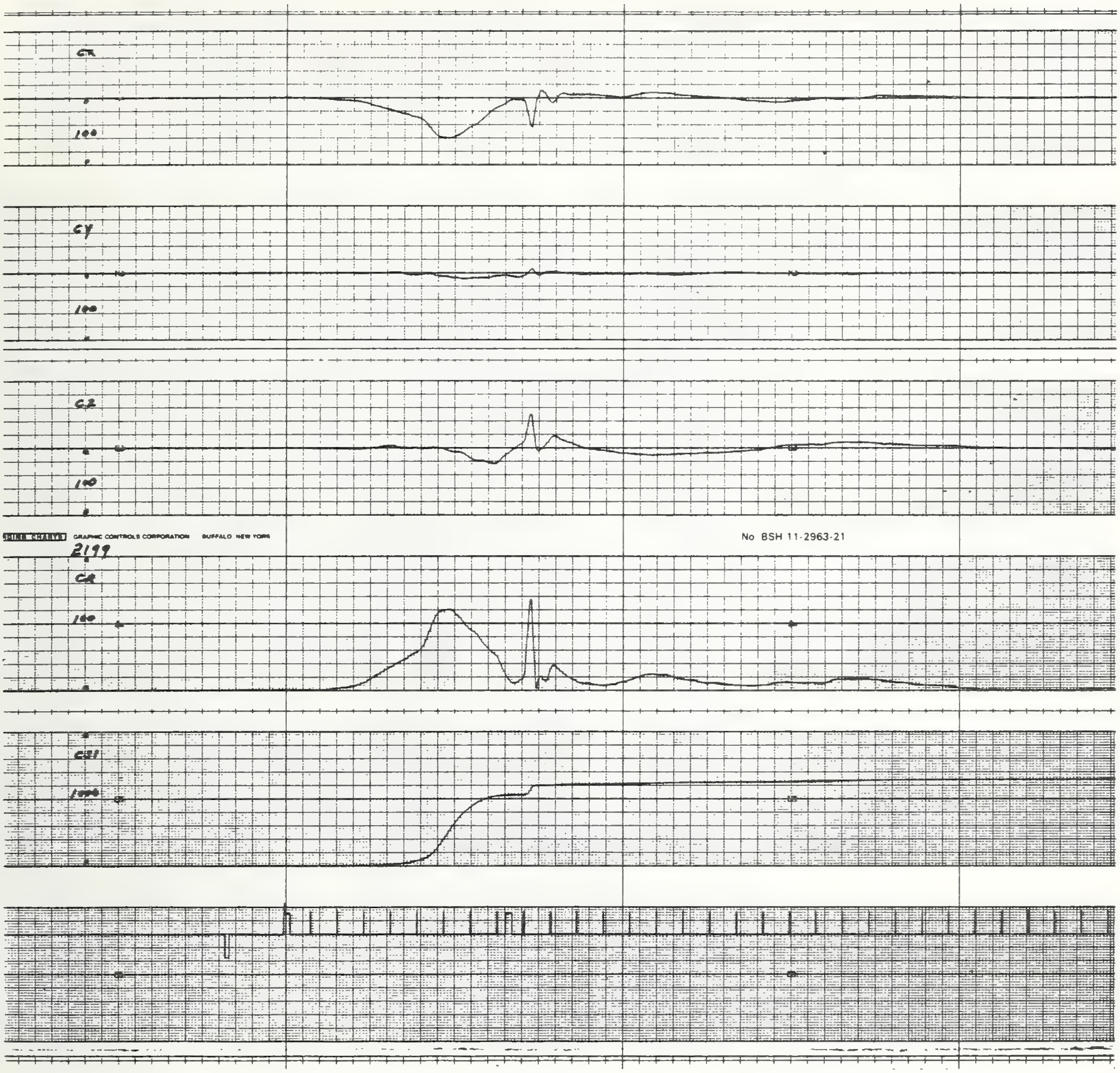

PRETEST


POST TEST

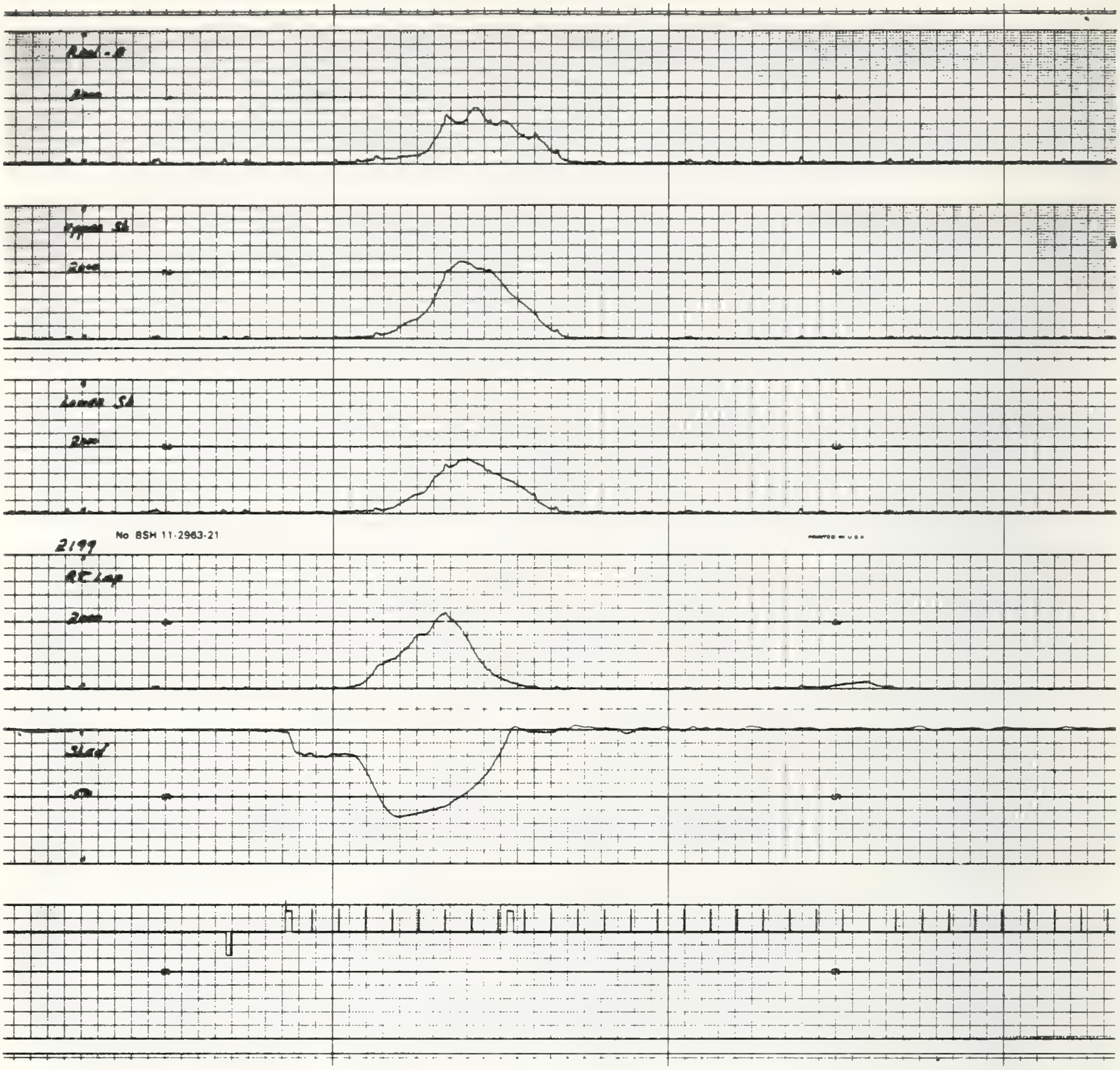
RUN 2199



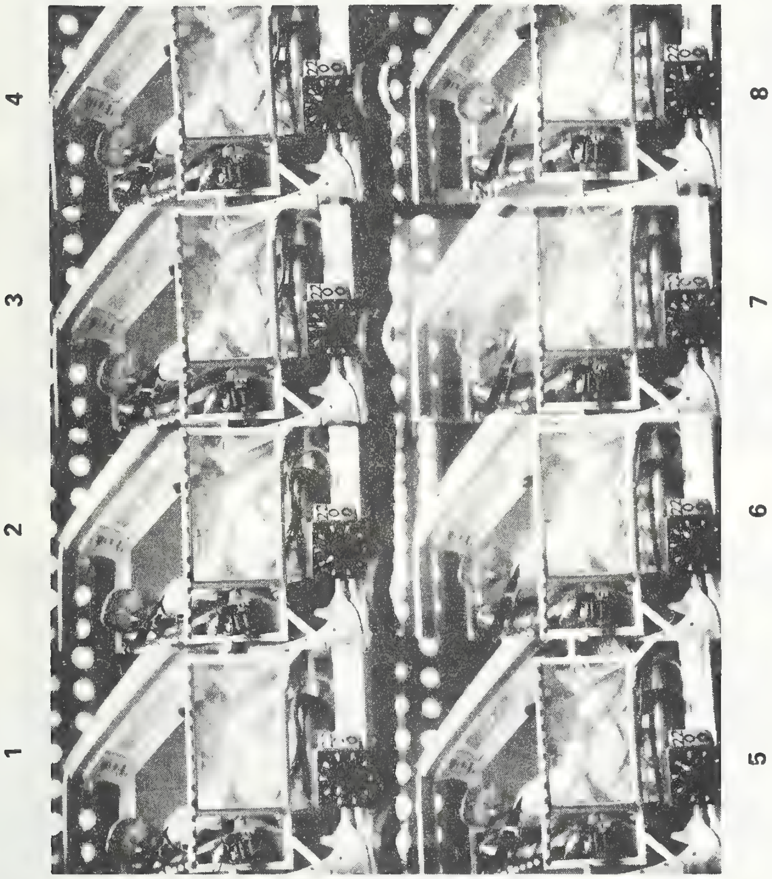
Time = 10 ms/division



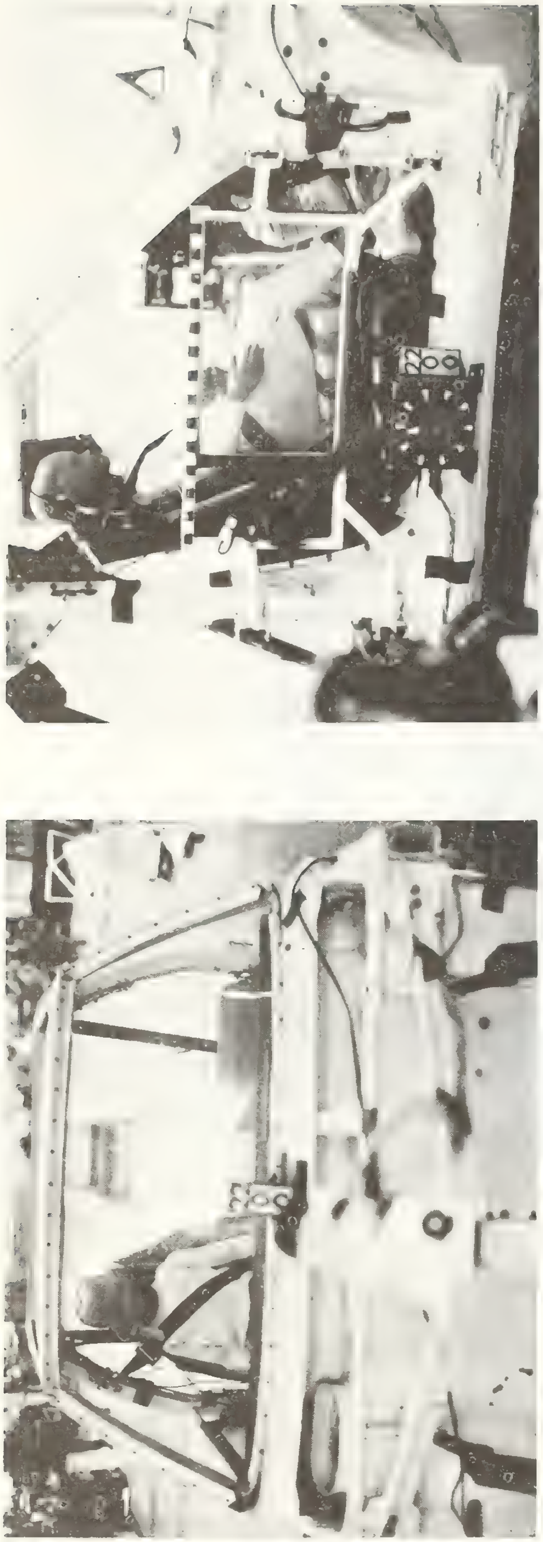
Time = 10 ms/division



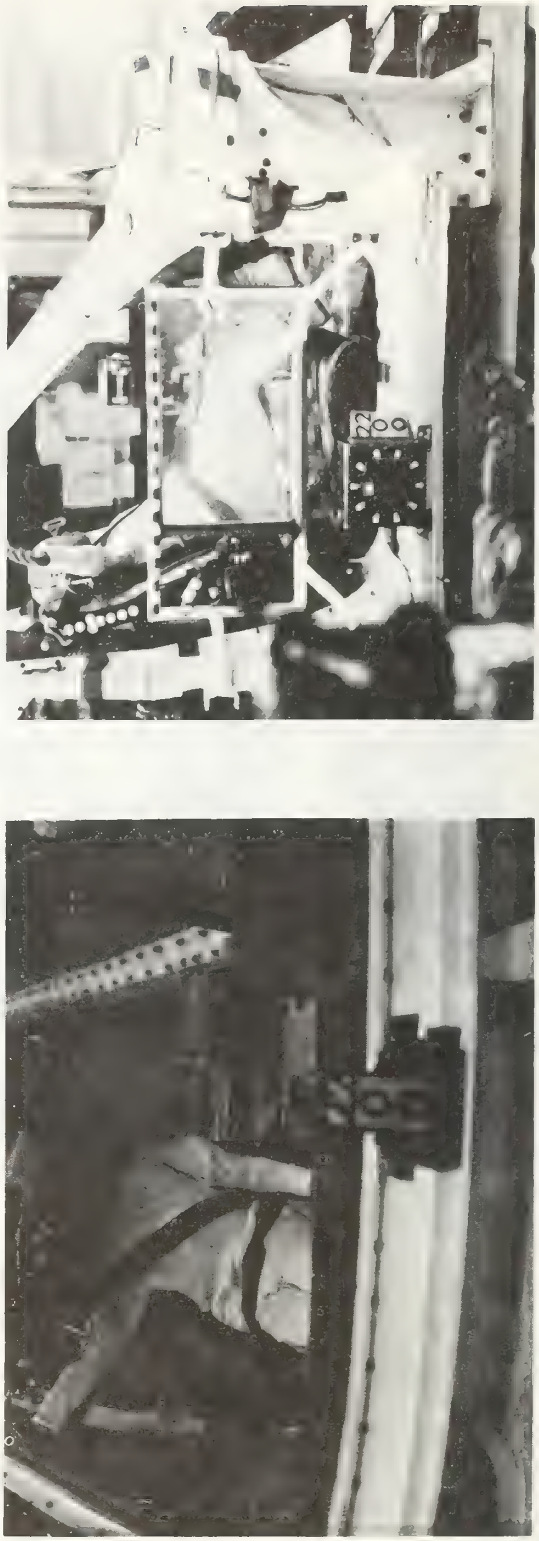
Time = 10 ms/division



RUN 2200 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

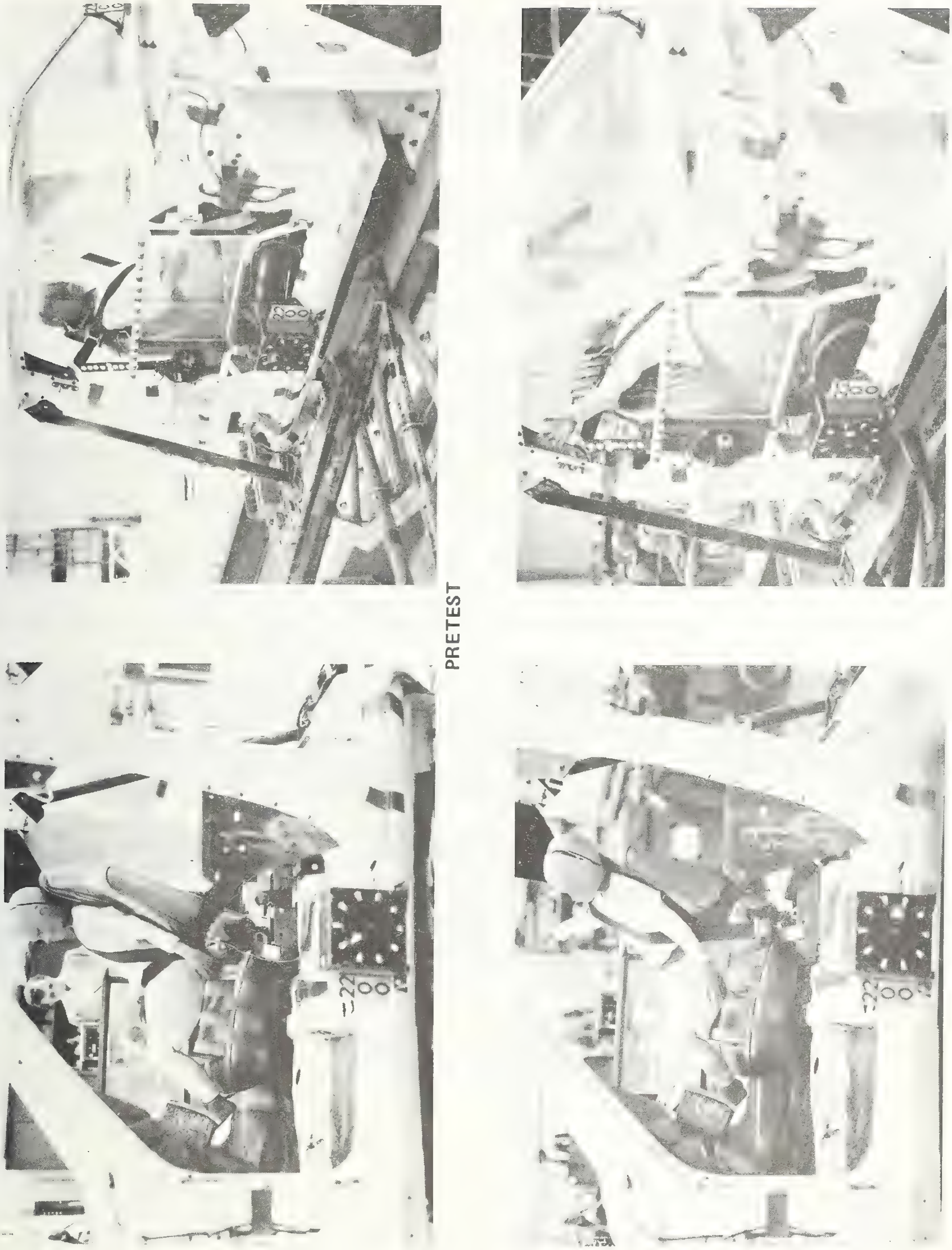


PRETEST



POST TEST

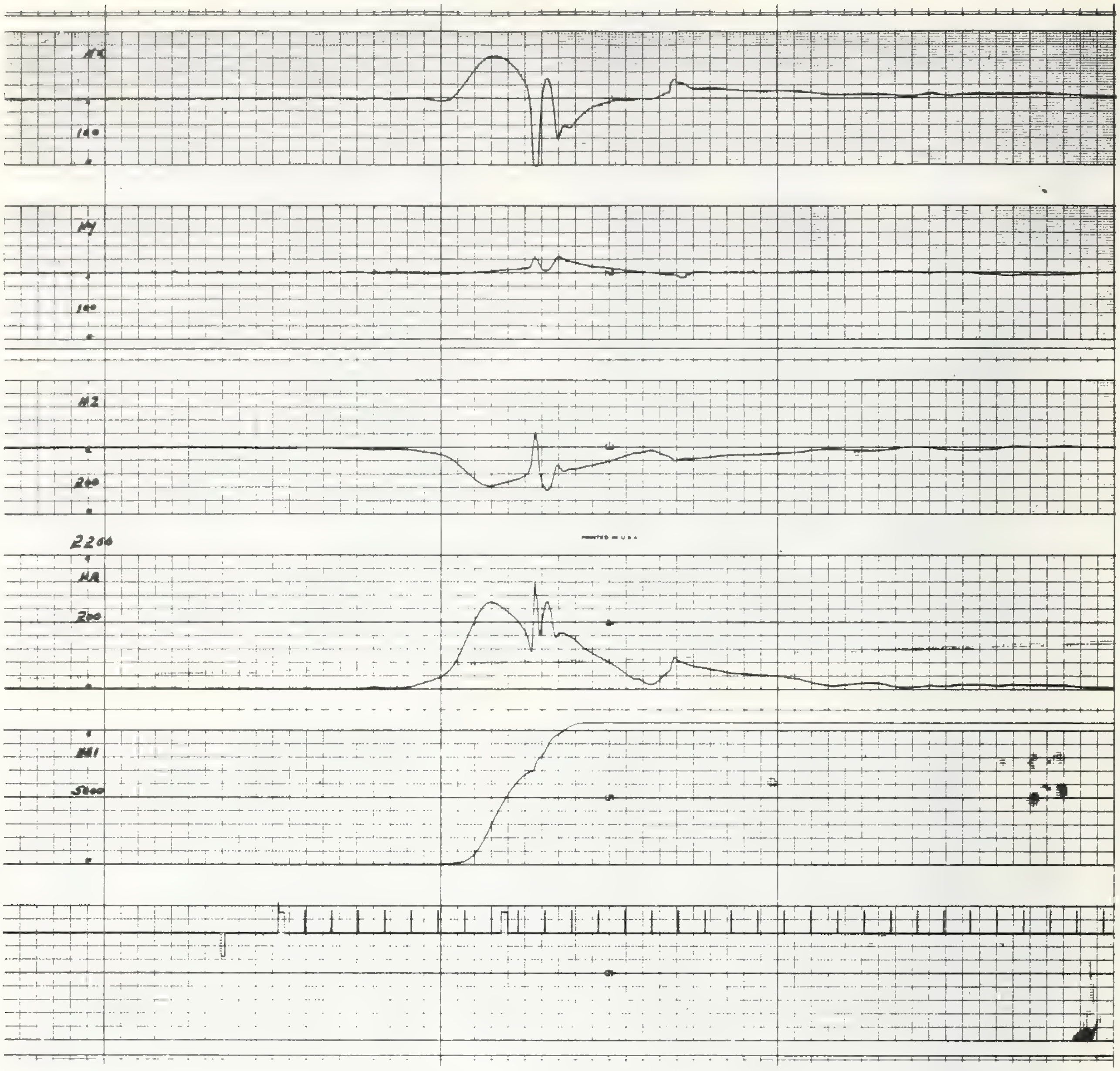
RUN 2200



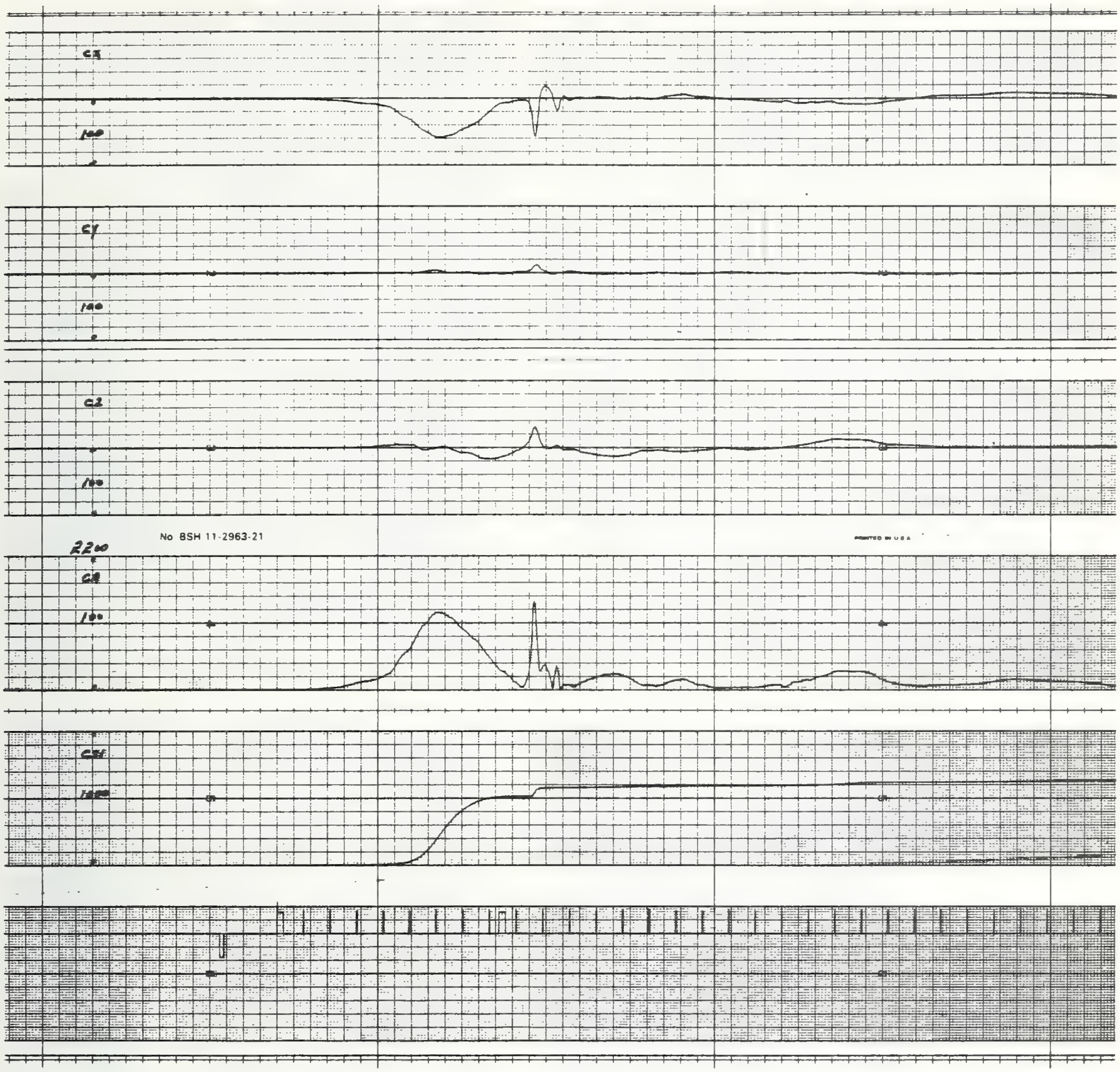
PRETEST

POST TEST

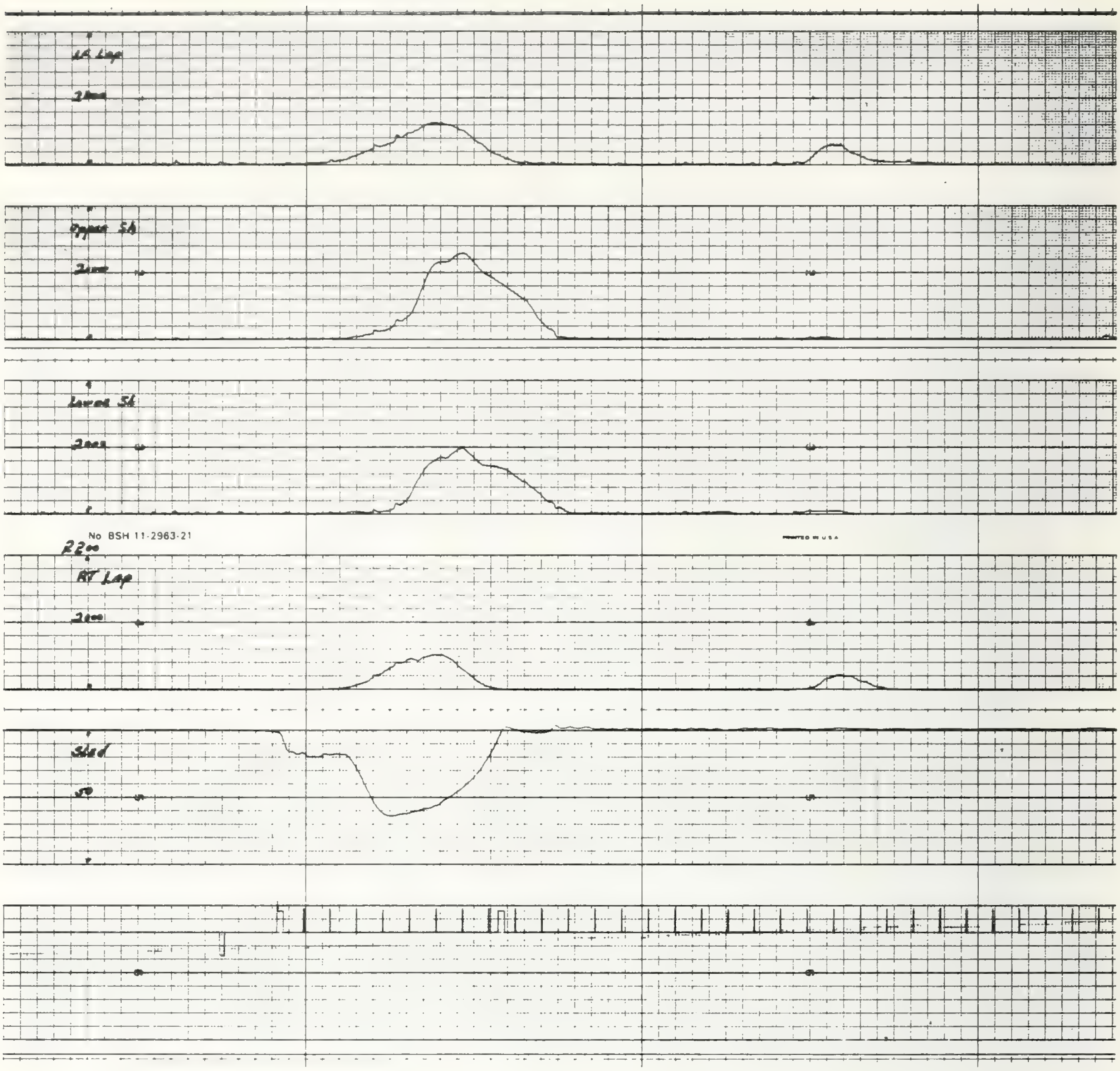
RUN 2200



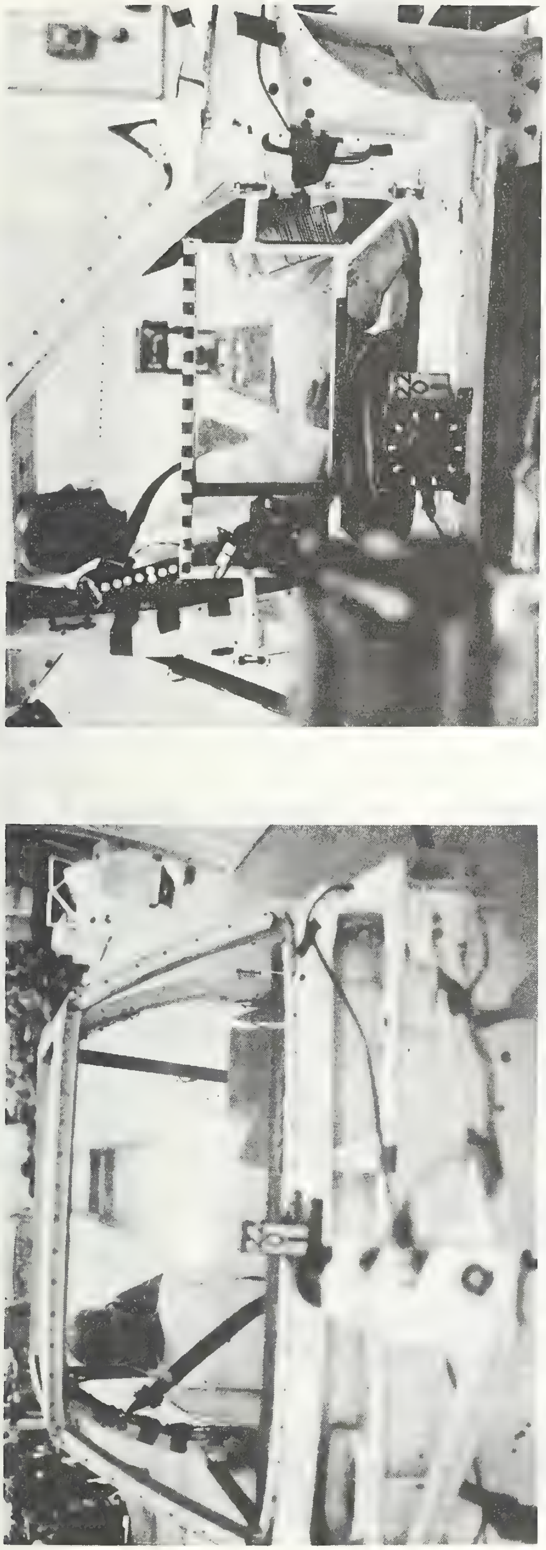
Time = 10 ms/division



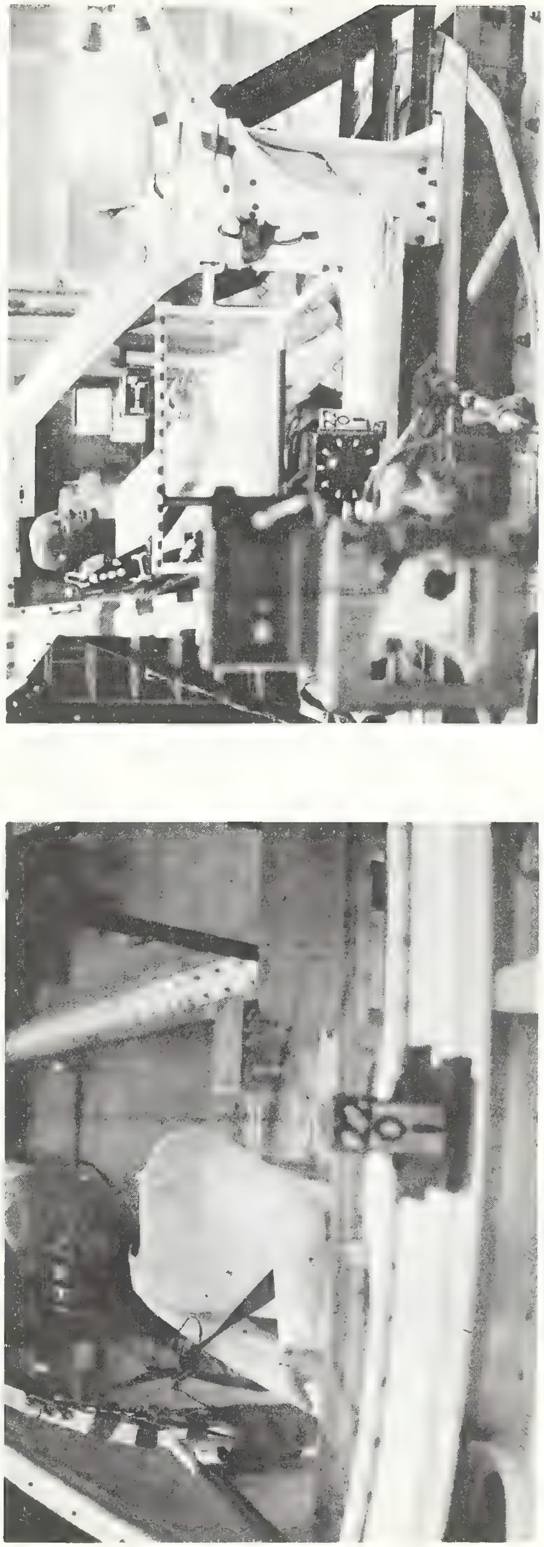
Time = 10 ms/division



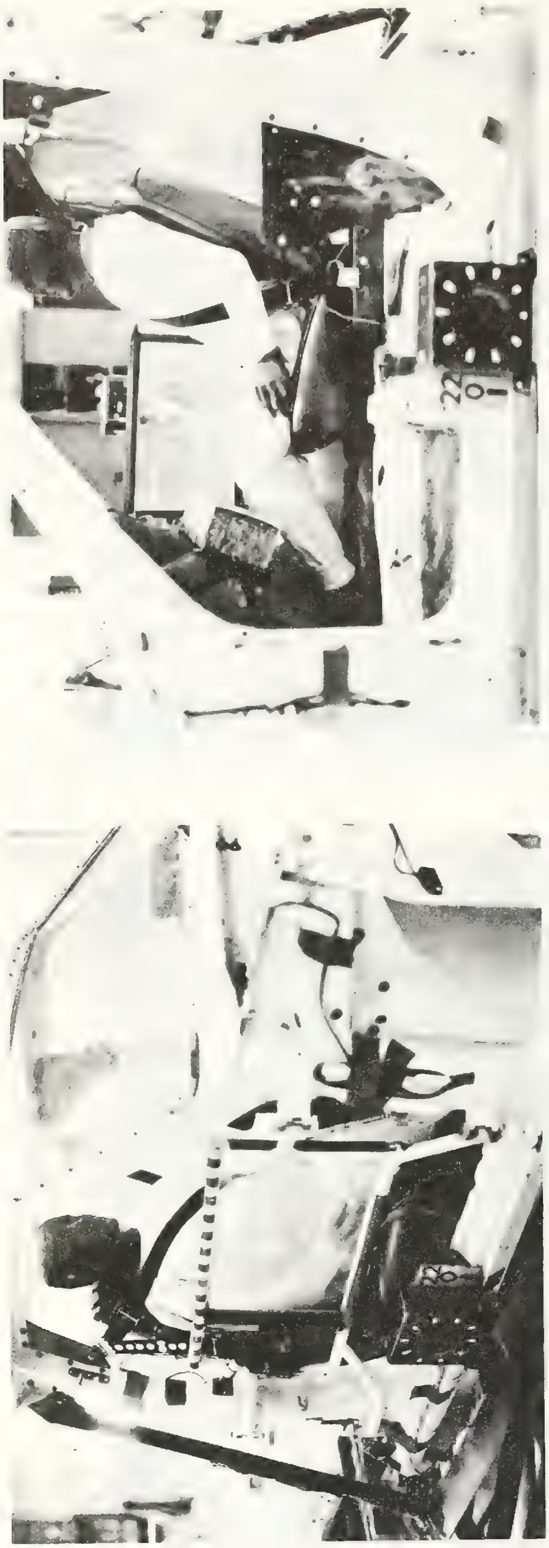
Time = 10 ms/division



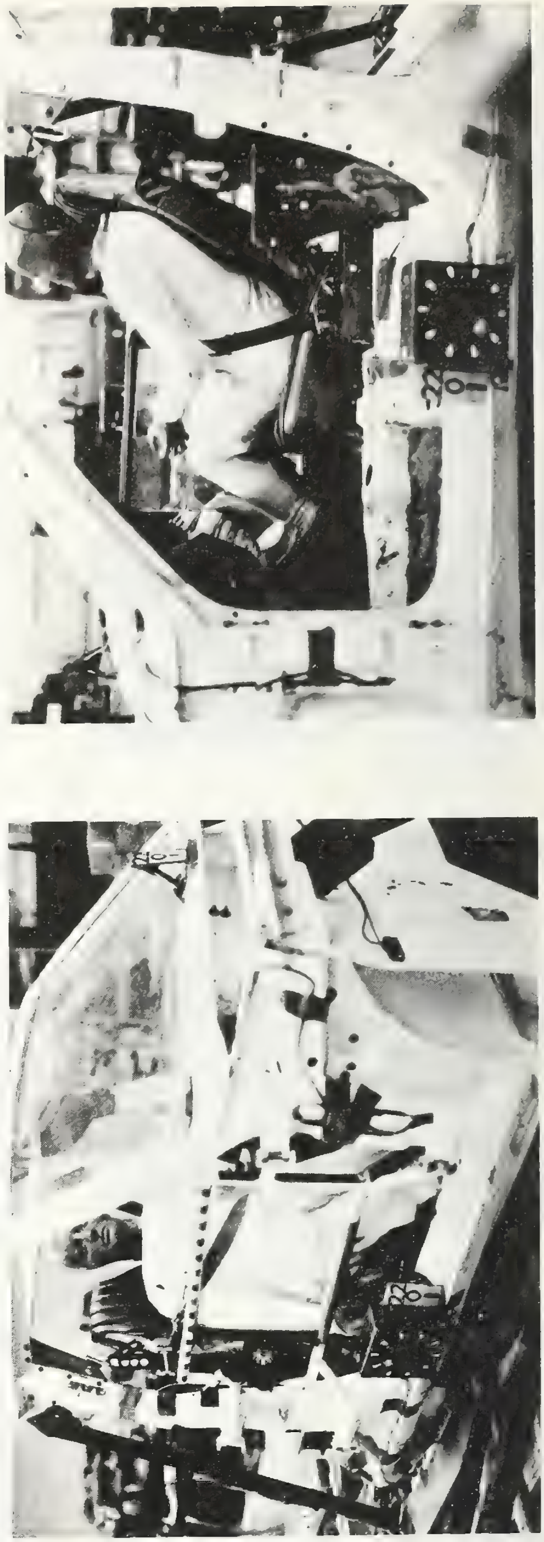
PRETEST



POST TEST
RUN 2201

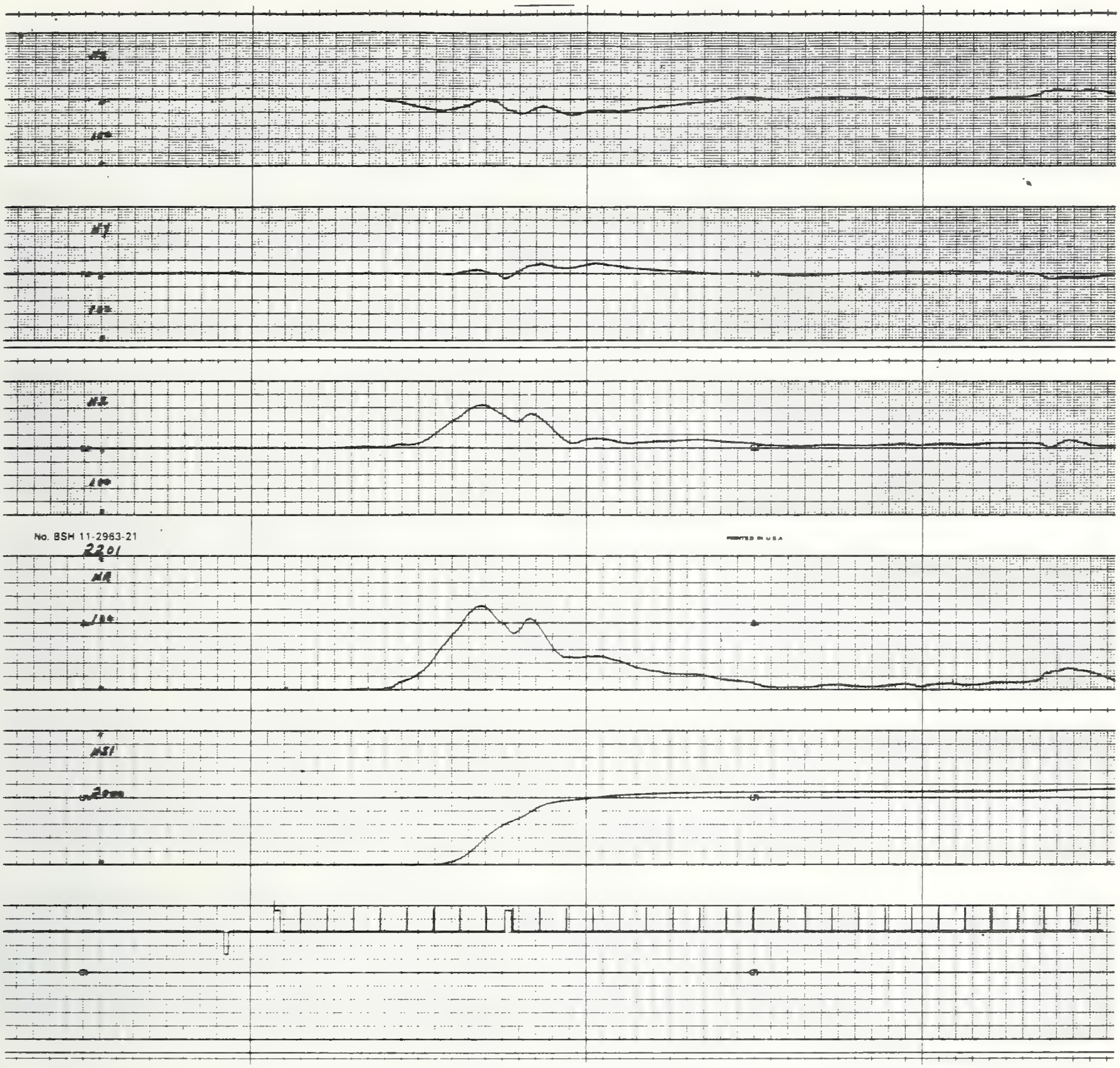


PRETEST

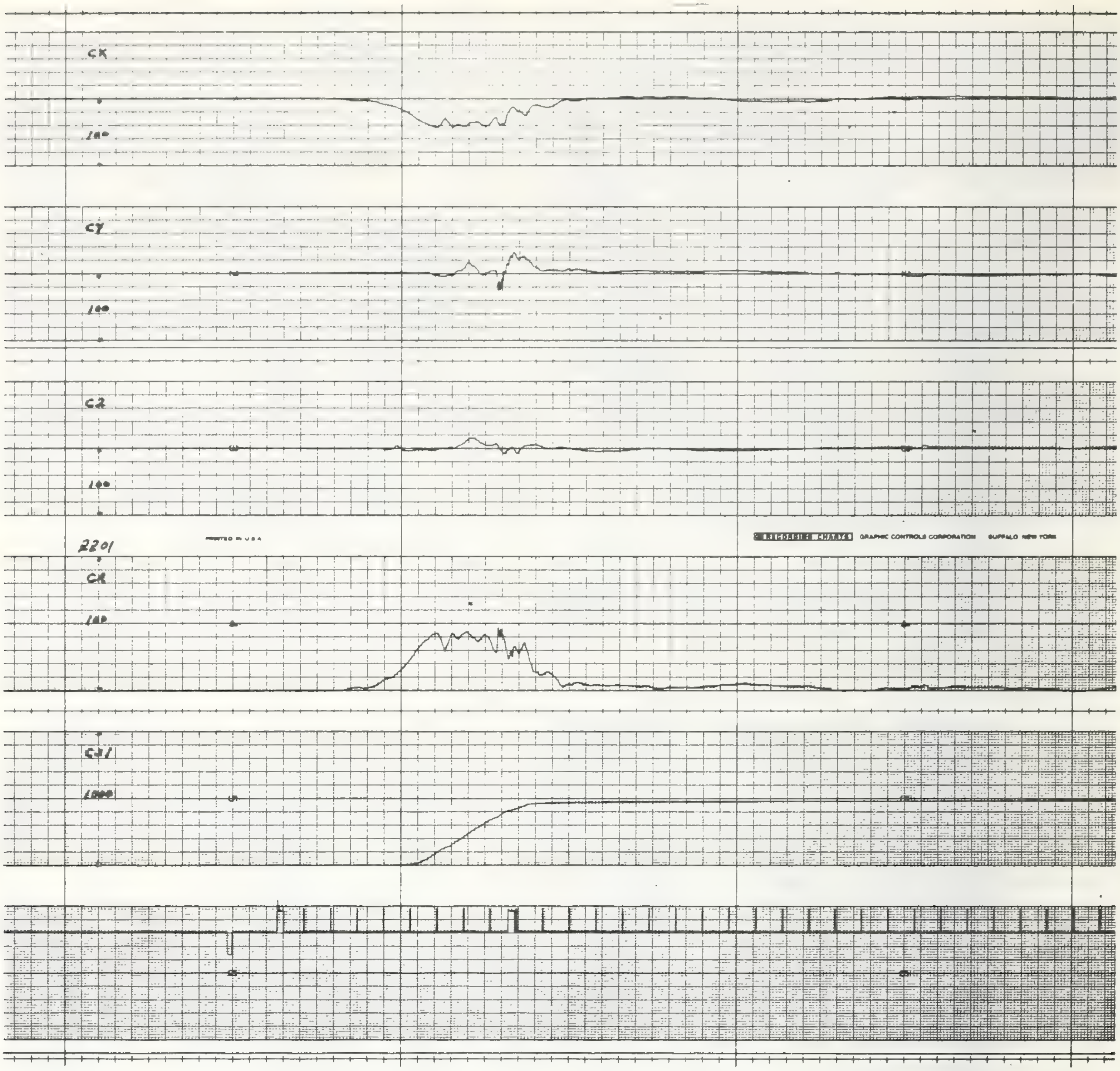


POST TEST

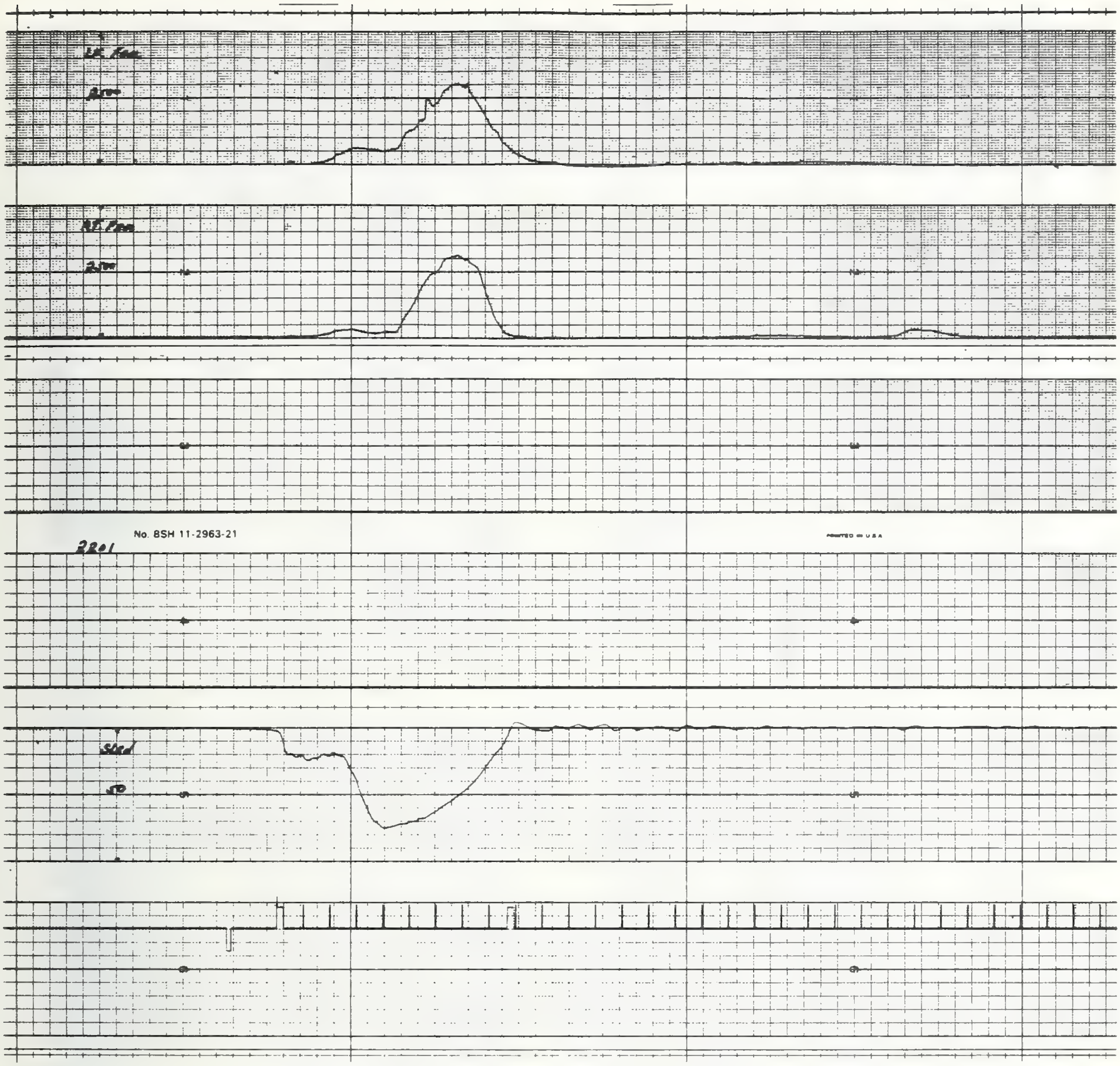
RUN 2201



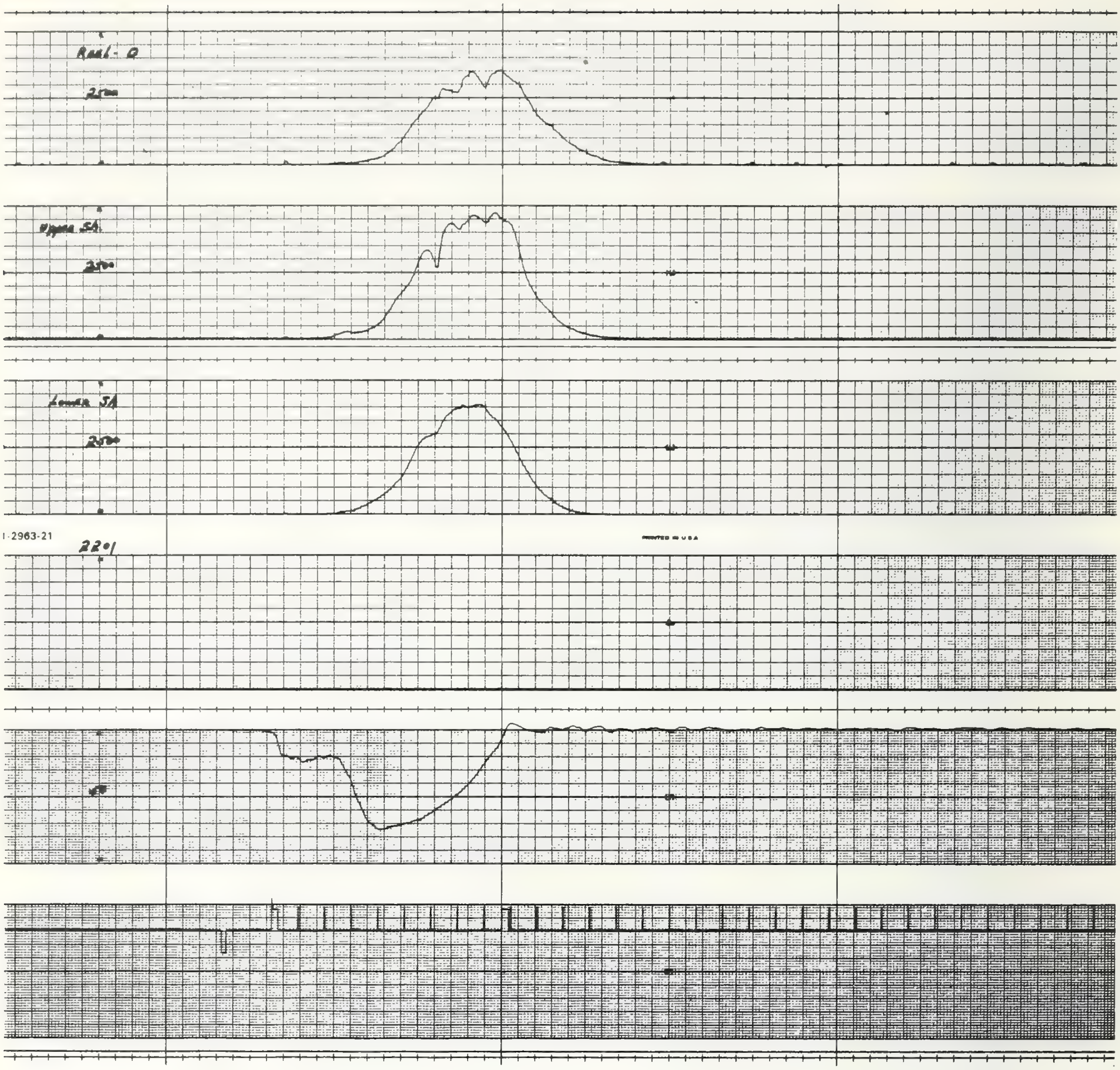
Time = 10 ms/division



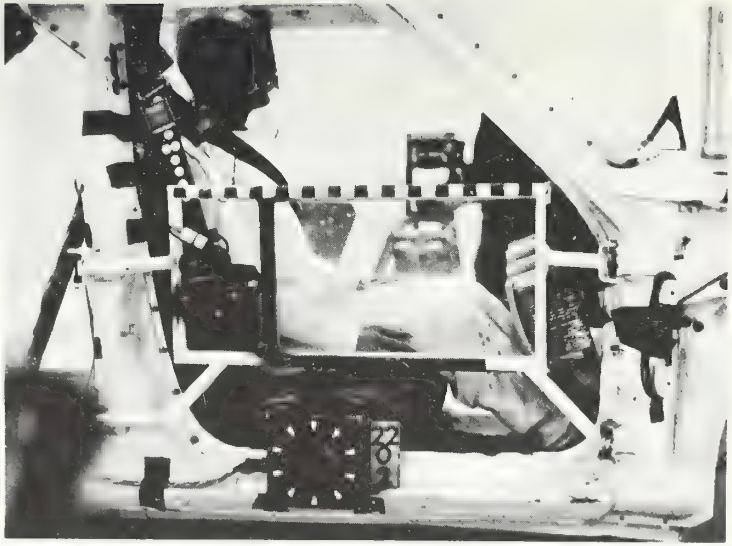
Time = 10 ms/division



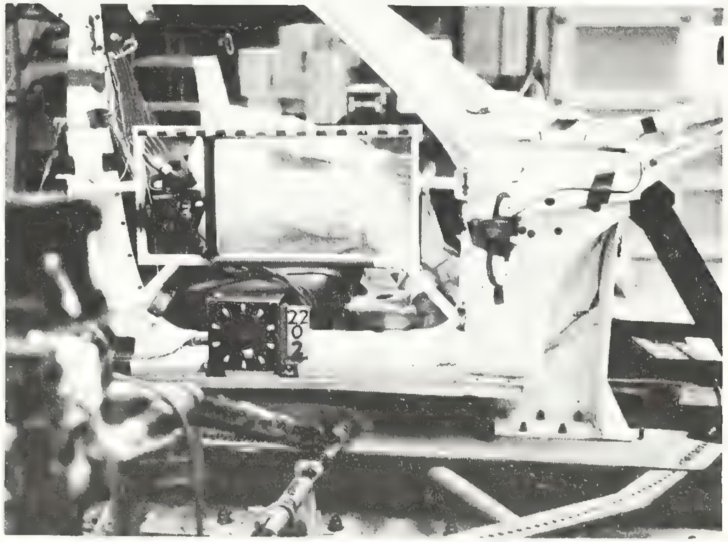
Time = 10 ms/division



Time = 10 ms/division

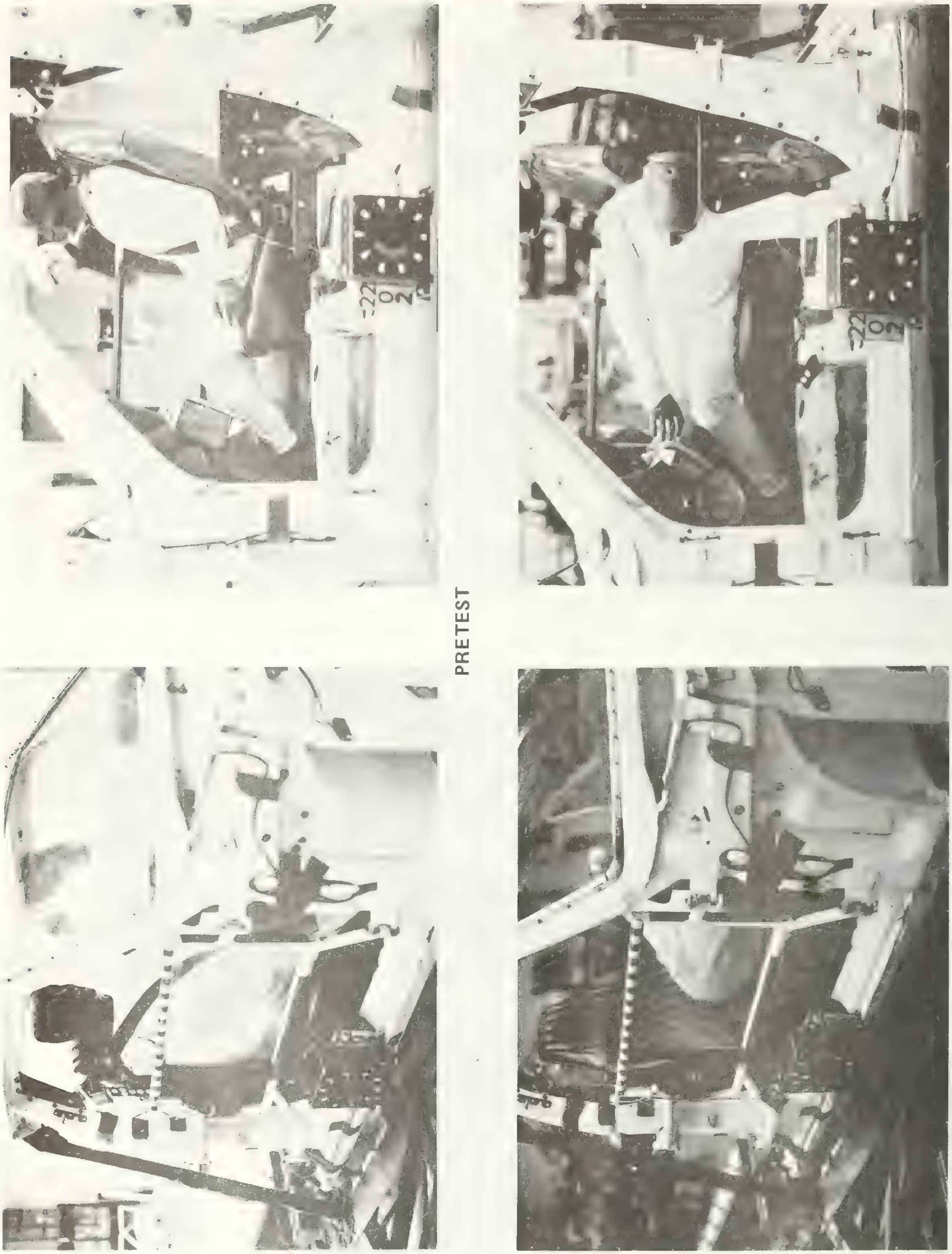


PRETEST



POST TEST

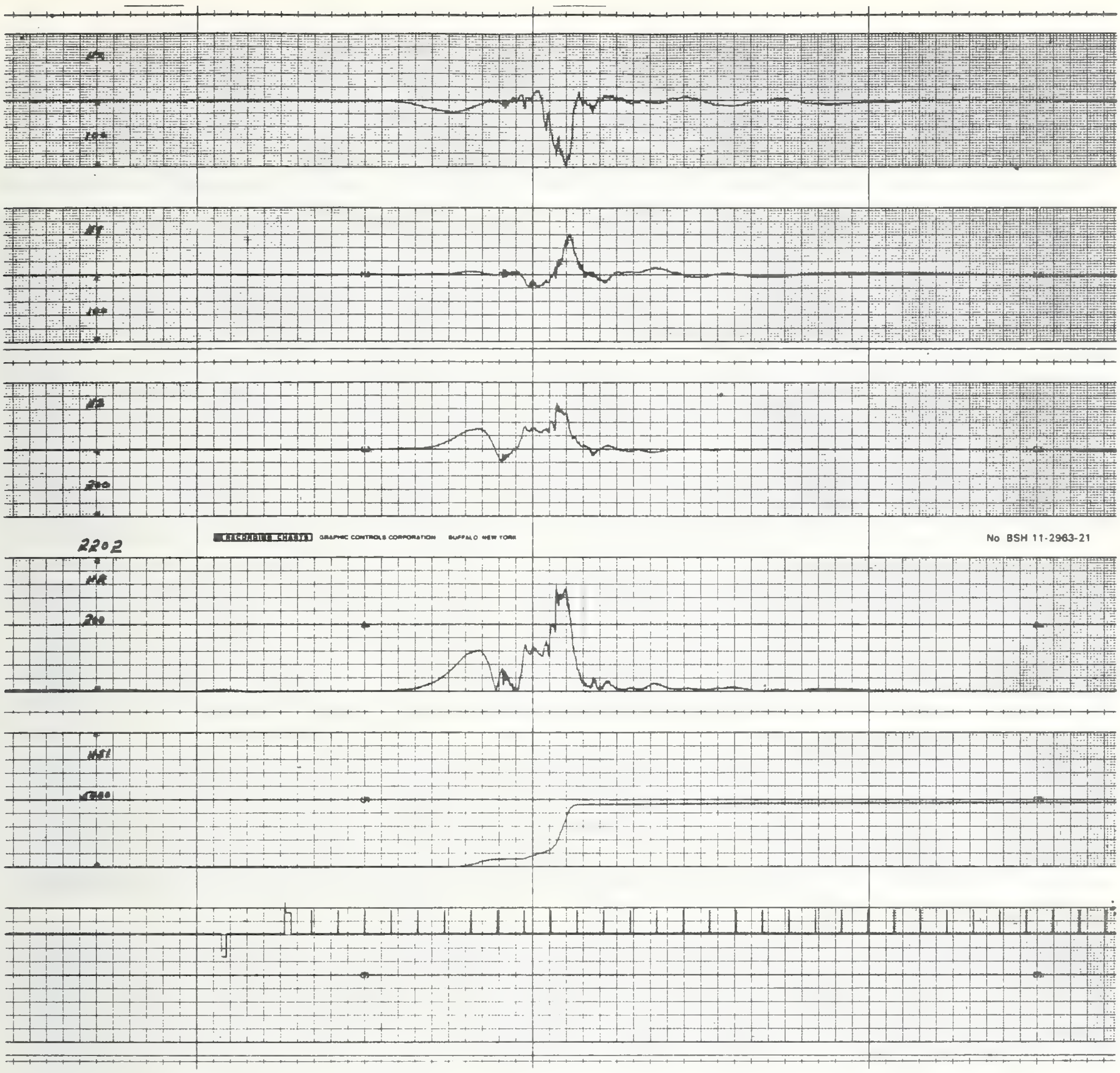
RUN 2202



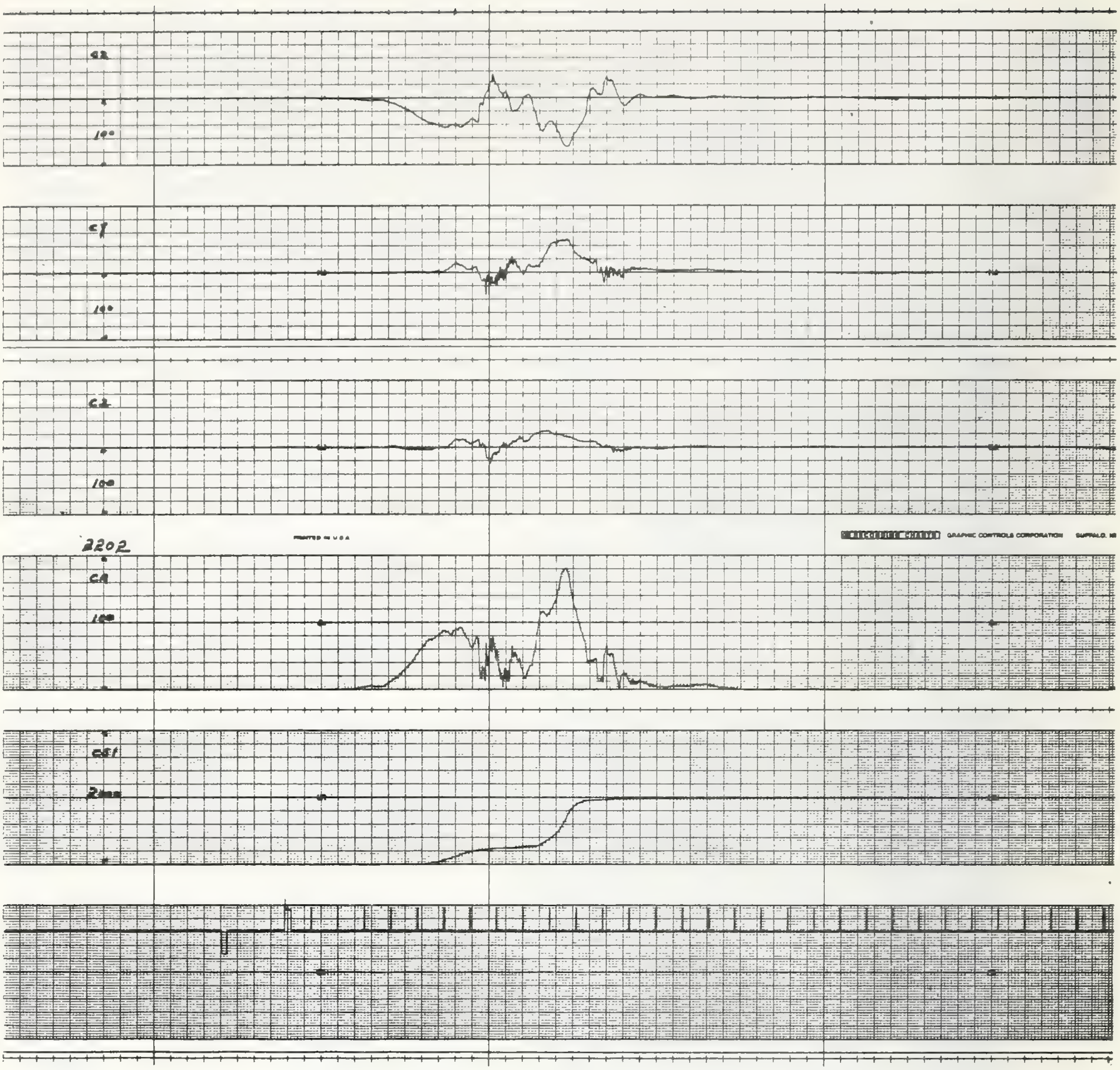
PRETEST

POST TEST

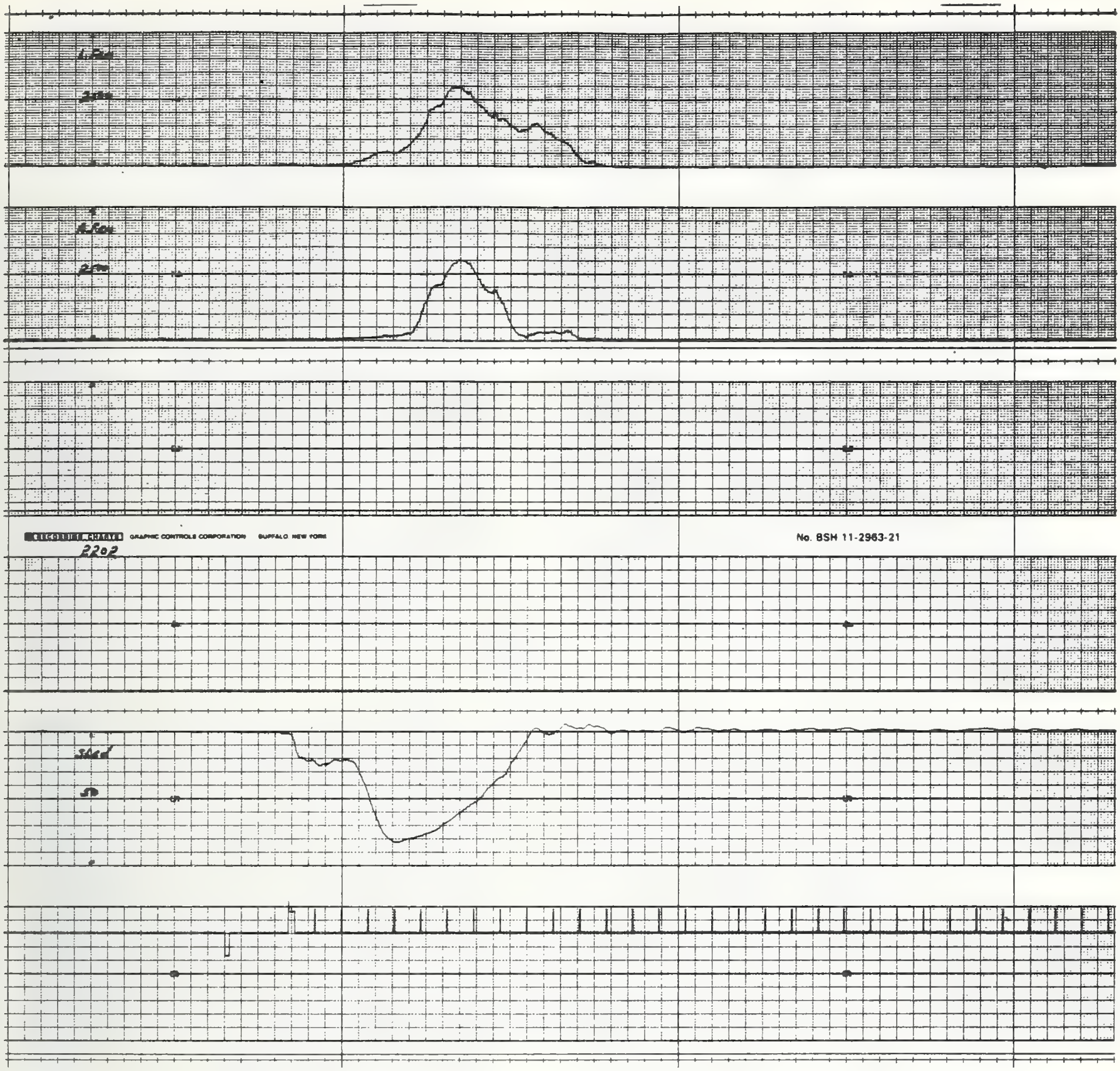
RUN 2202



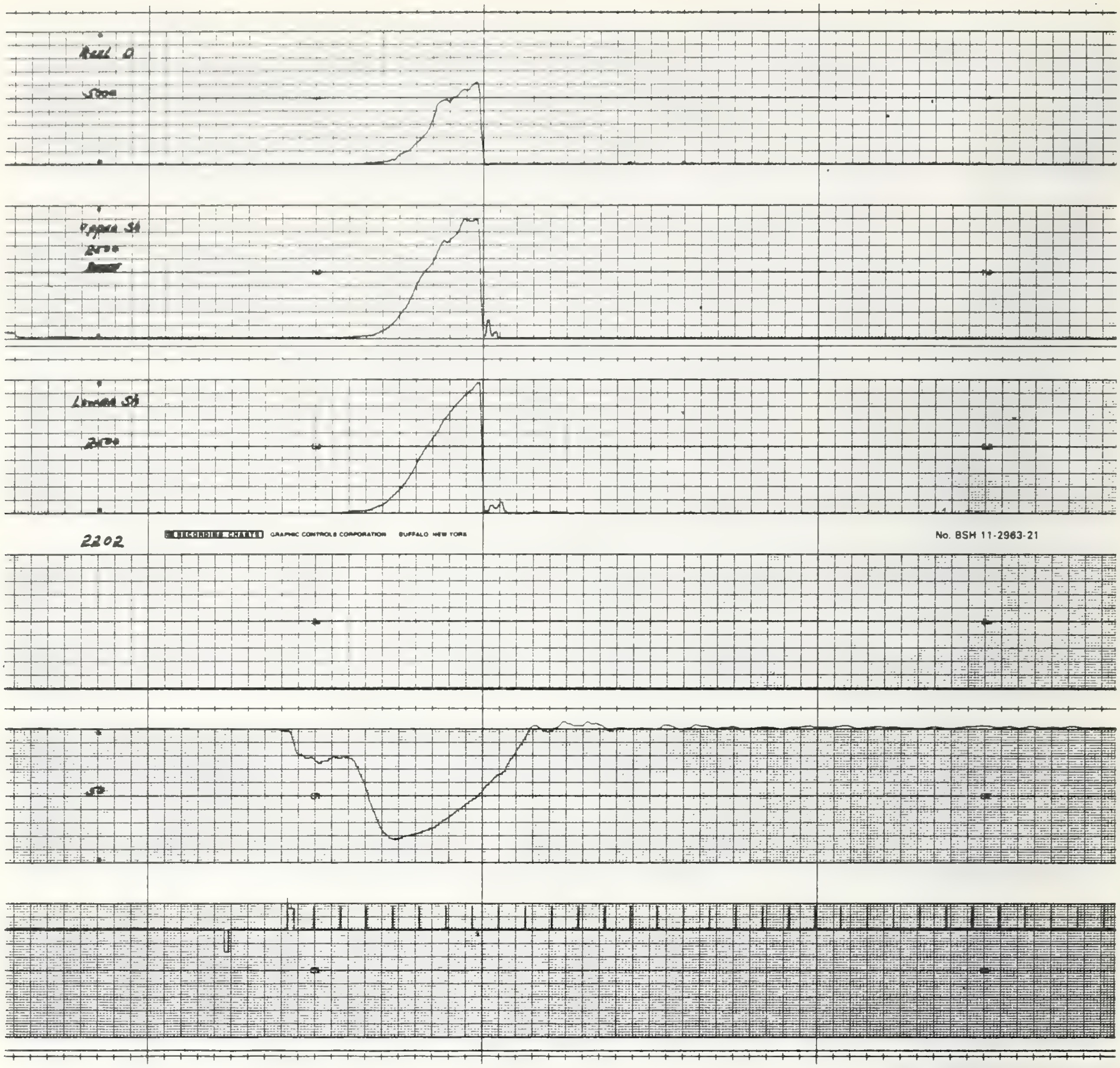
Time = 10 ms/division



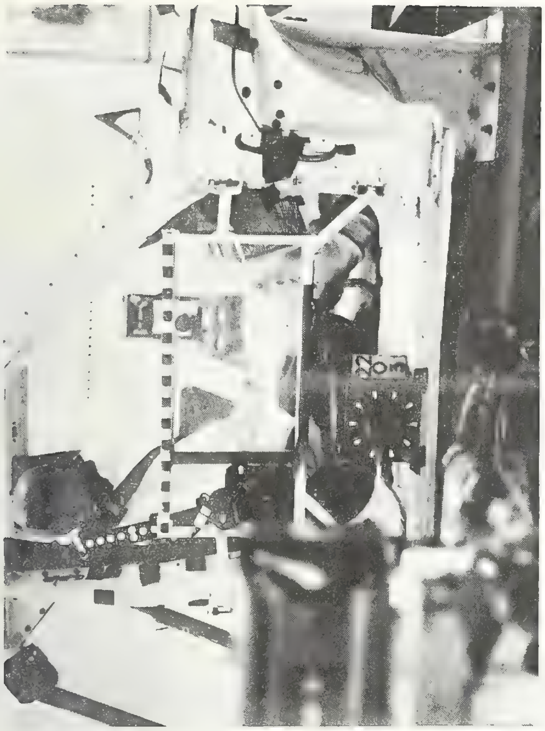
Time = 10 ms/division

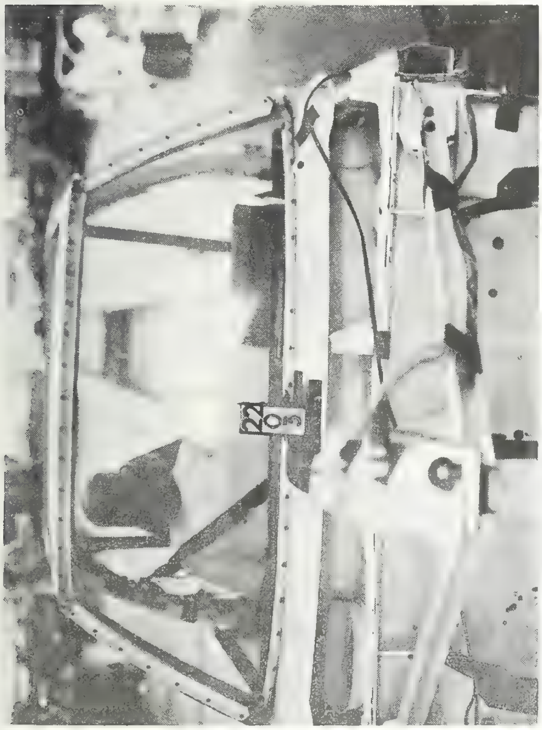


Time = 10 ms/division

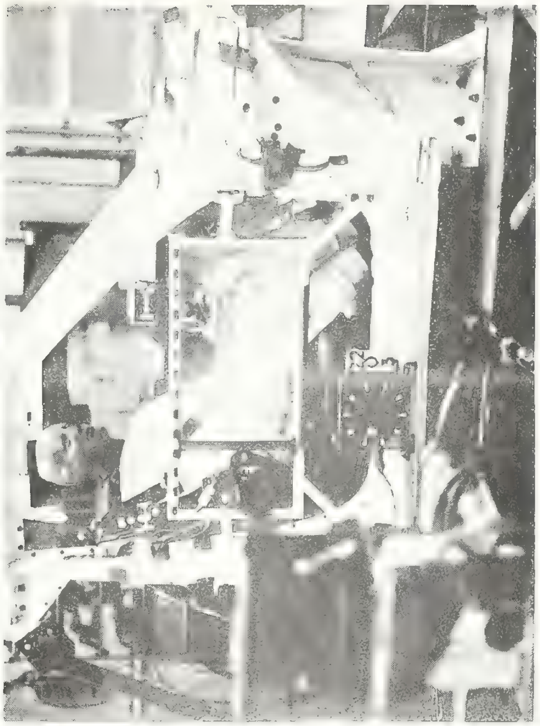


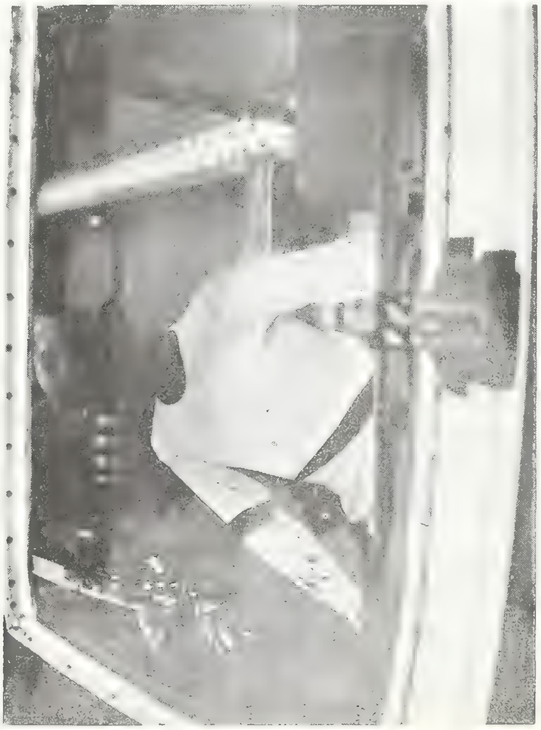
Time = 10 ms/division





PRETEST



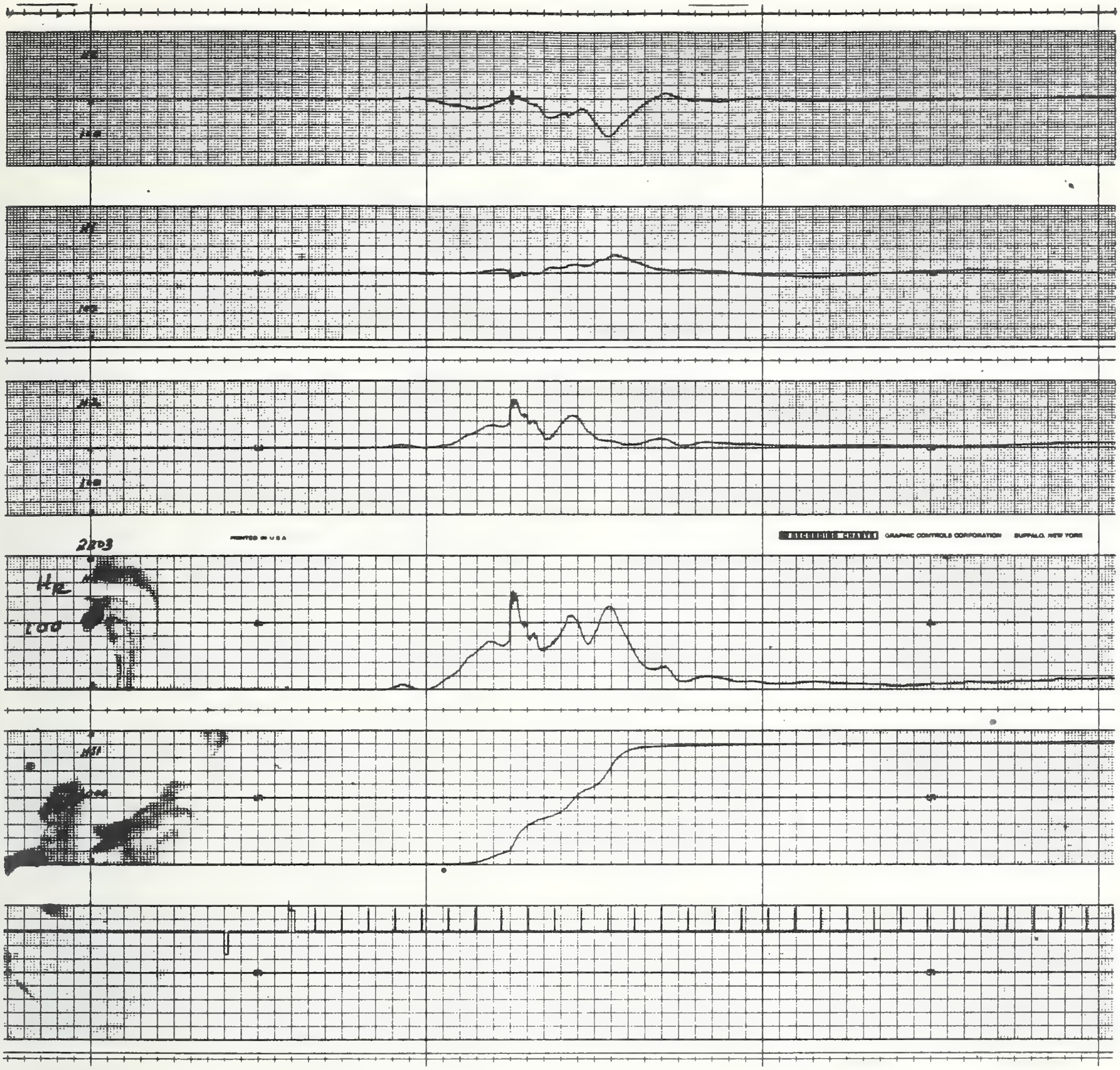


POST TEST

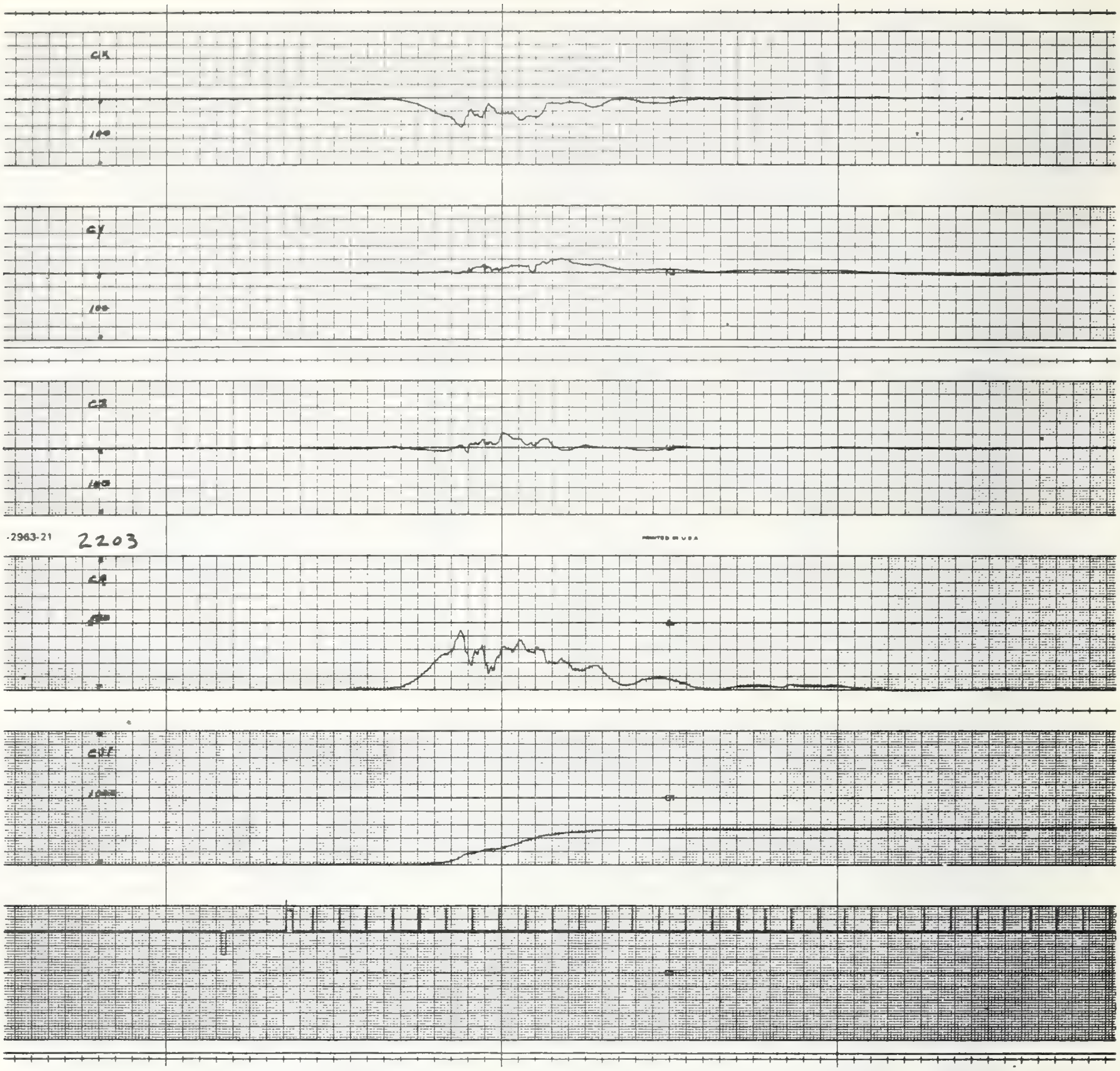
RUN 2203

PRETEST

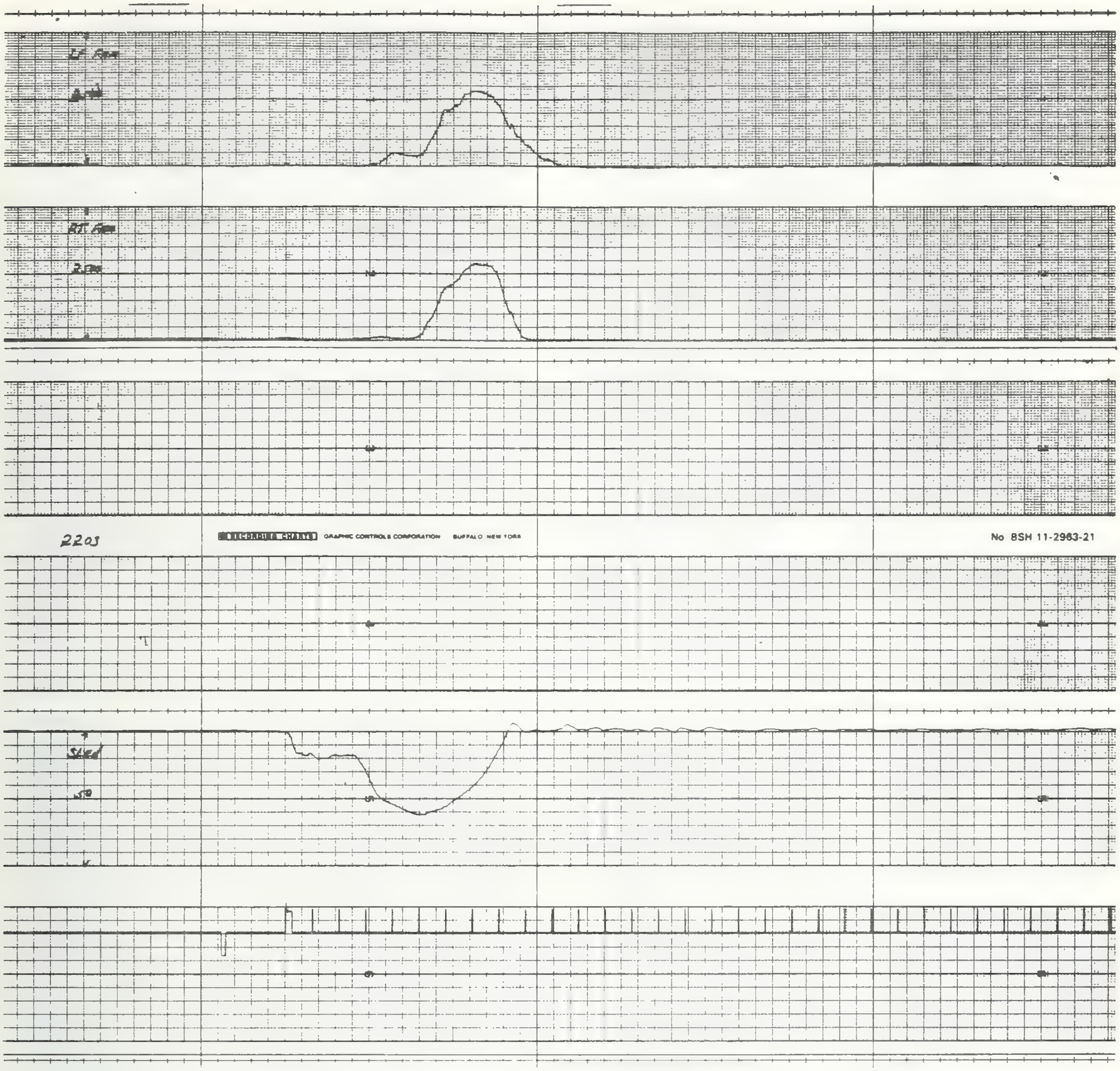
POST TEST
RUN 2203



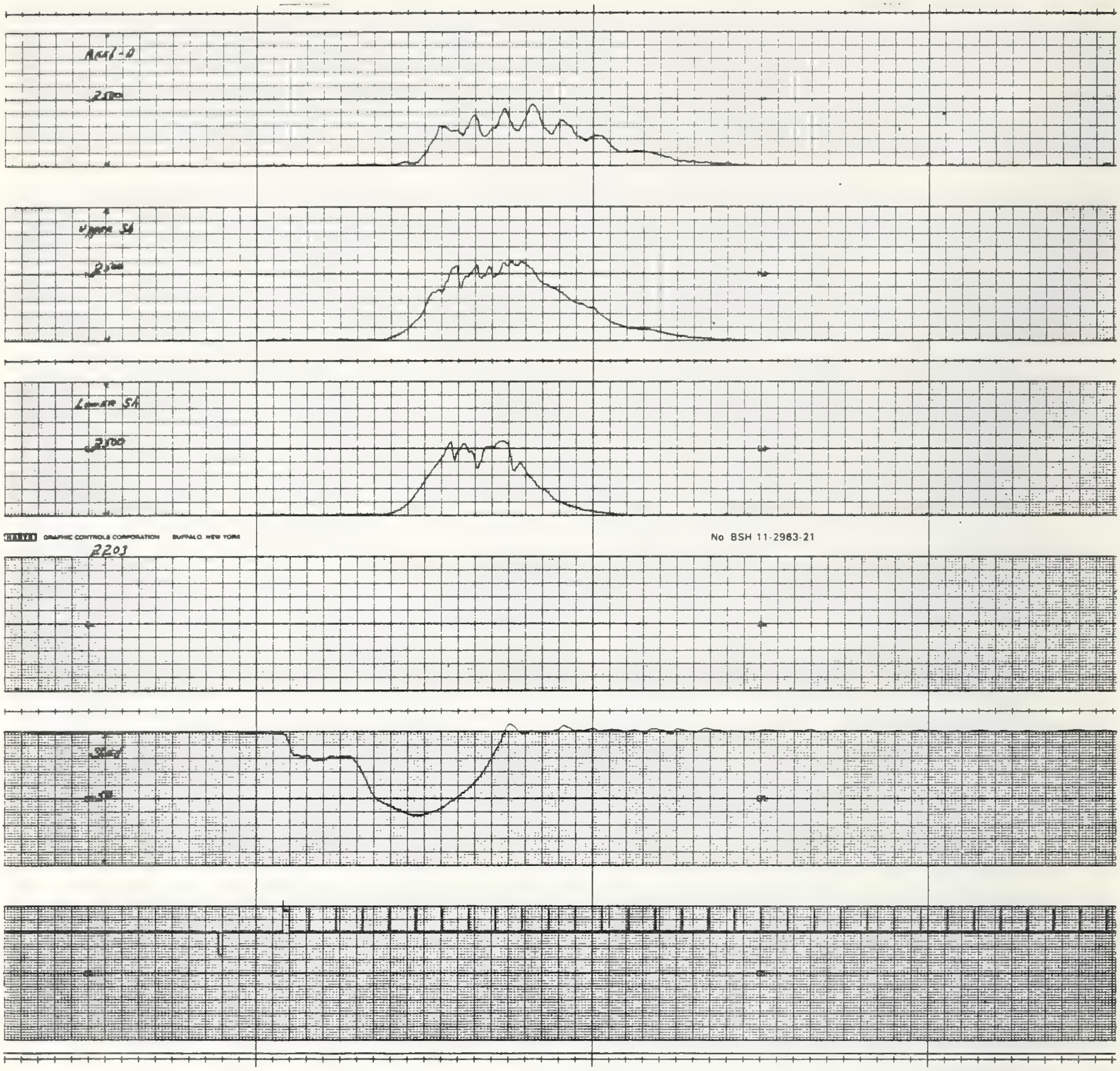
Time = 10 ms/division



Time = 10 ms/division

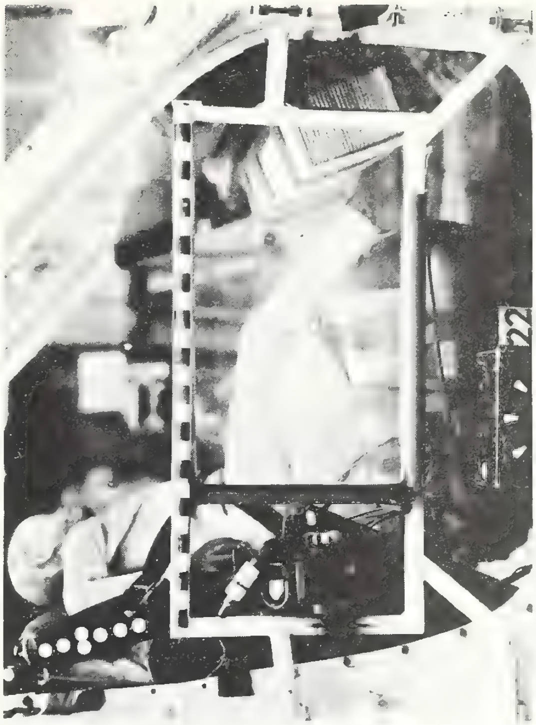


Time = 10 ms/division

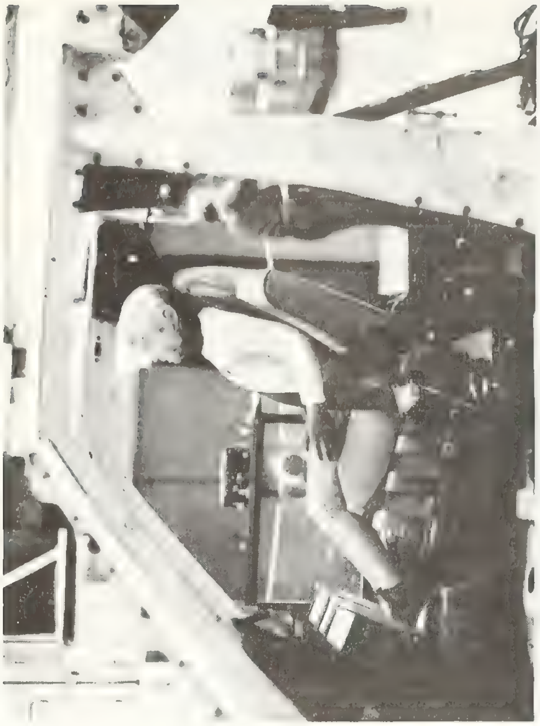


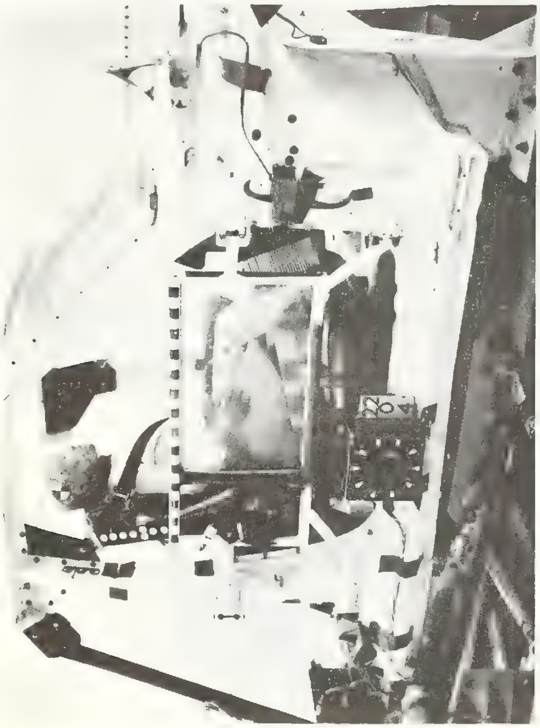
Time = 10 ms/division

PRETEST

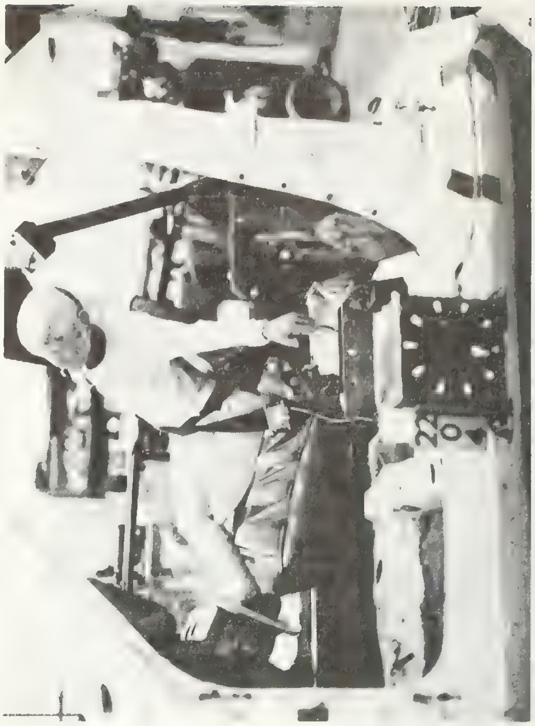


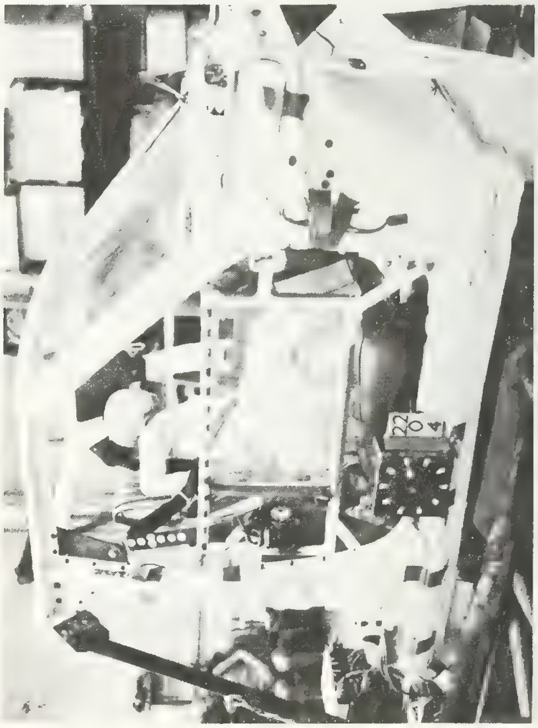
POST TEST
RUN 2204



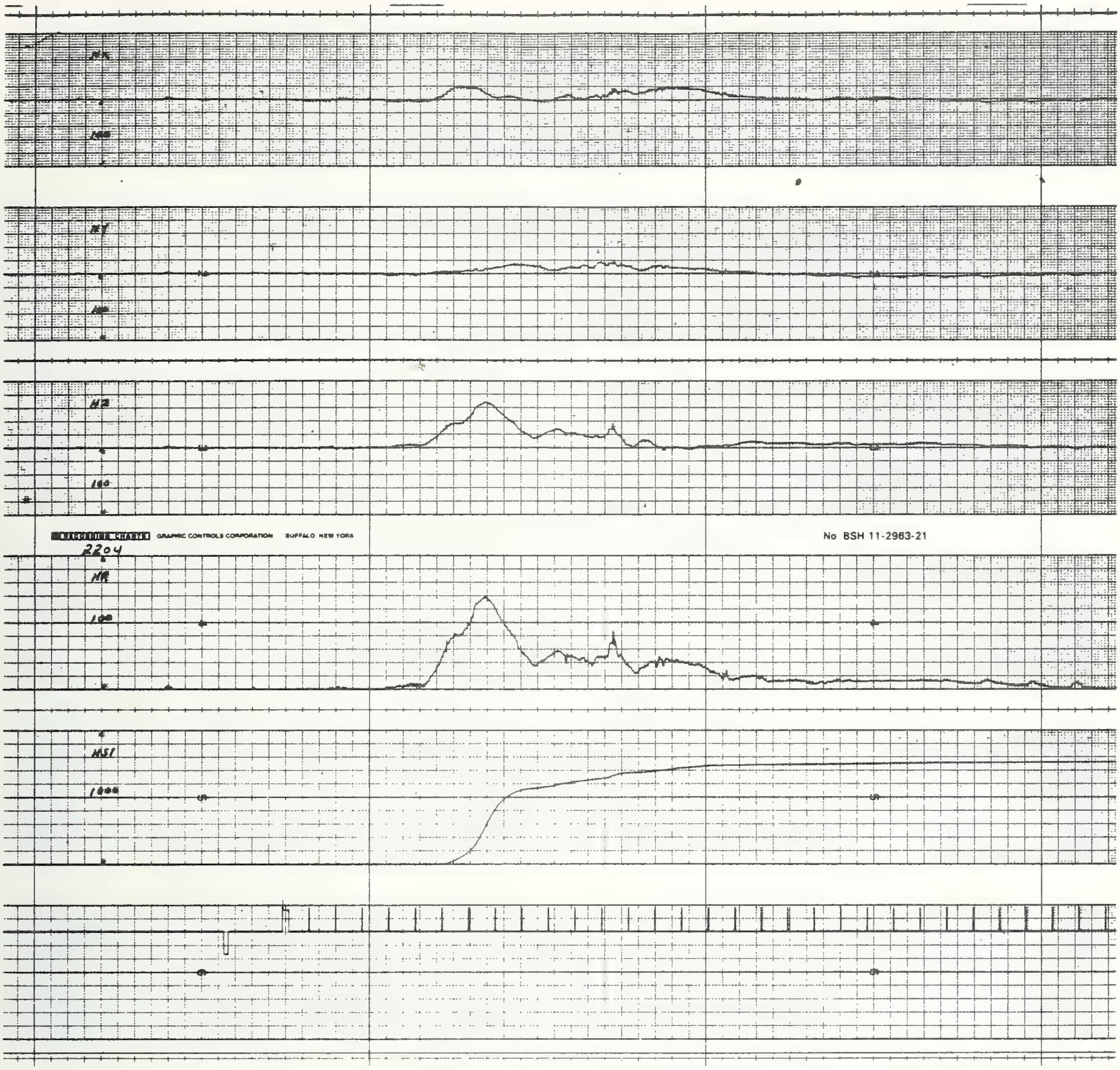


PRETEST

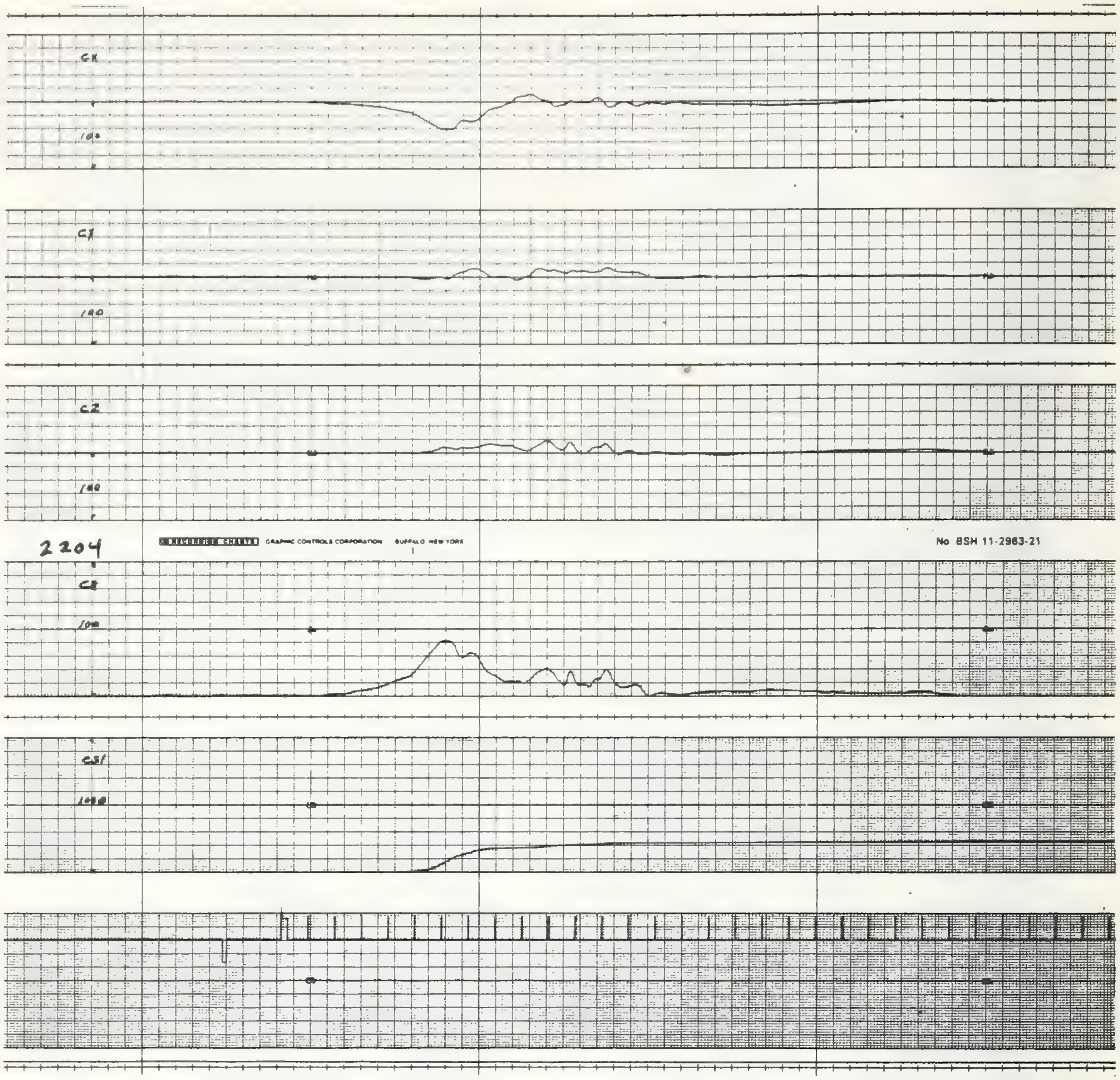




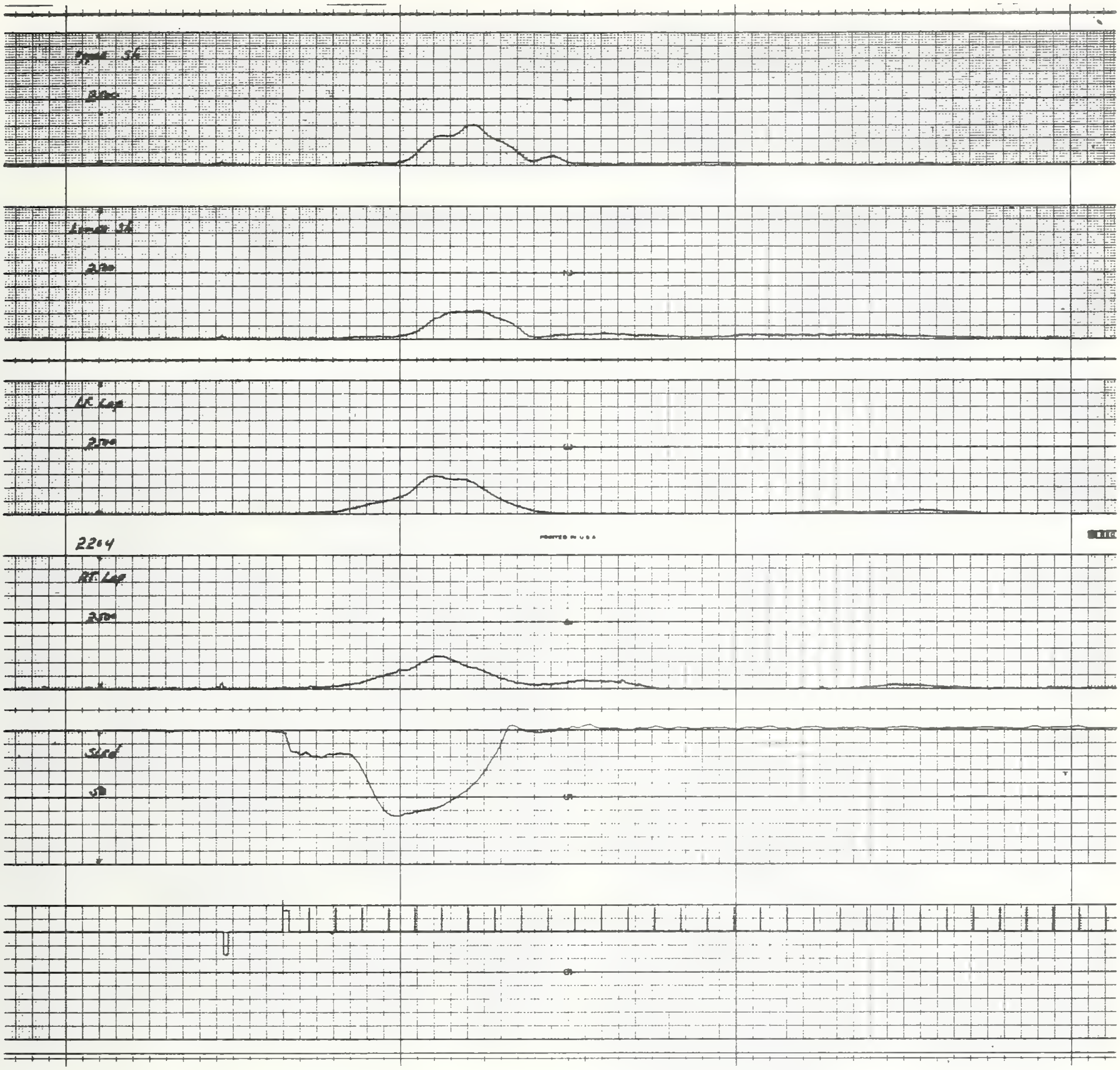
POST TEST
RUN 2204



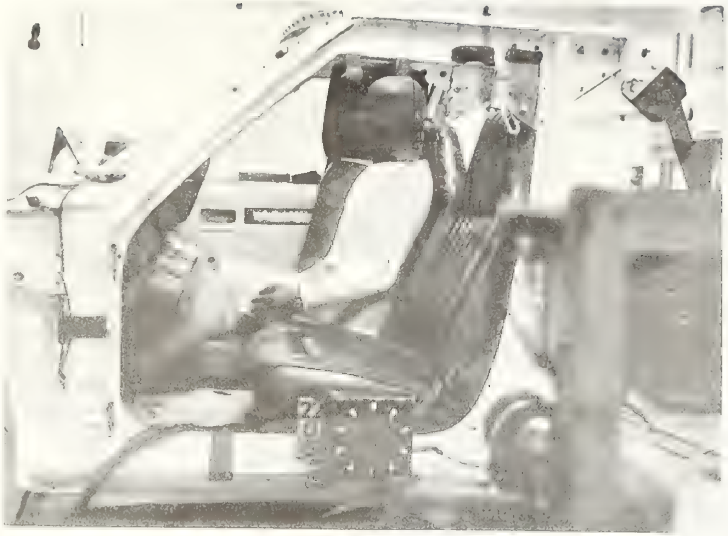
Time = 10 ms/division



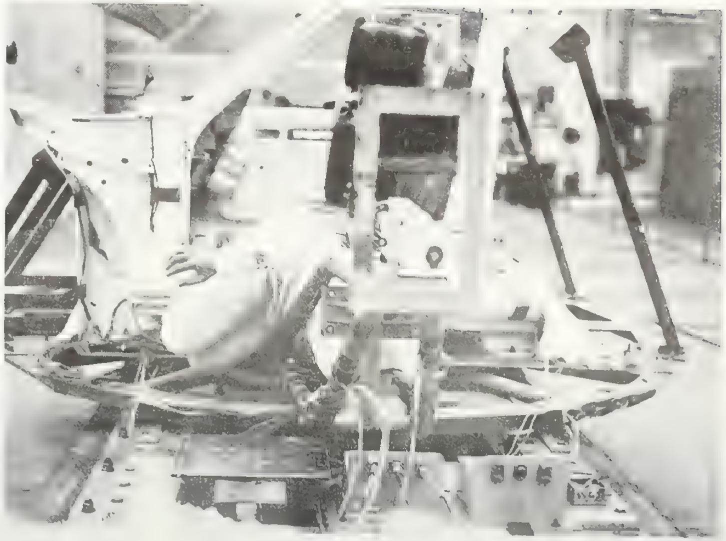
Time = 10 ms/division



Time = 10 ms/division

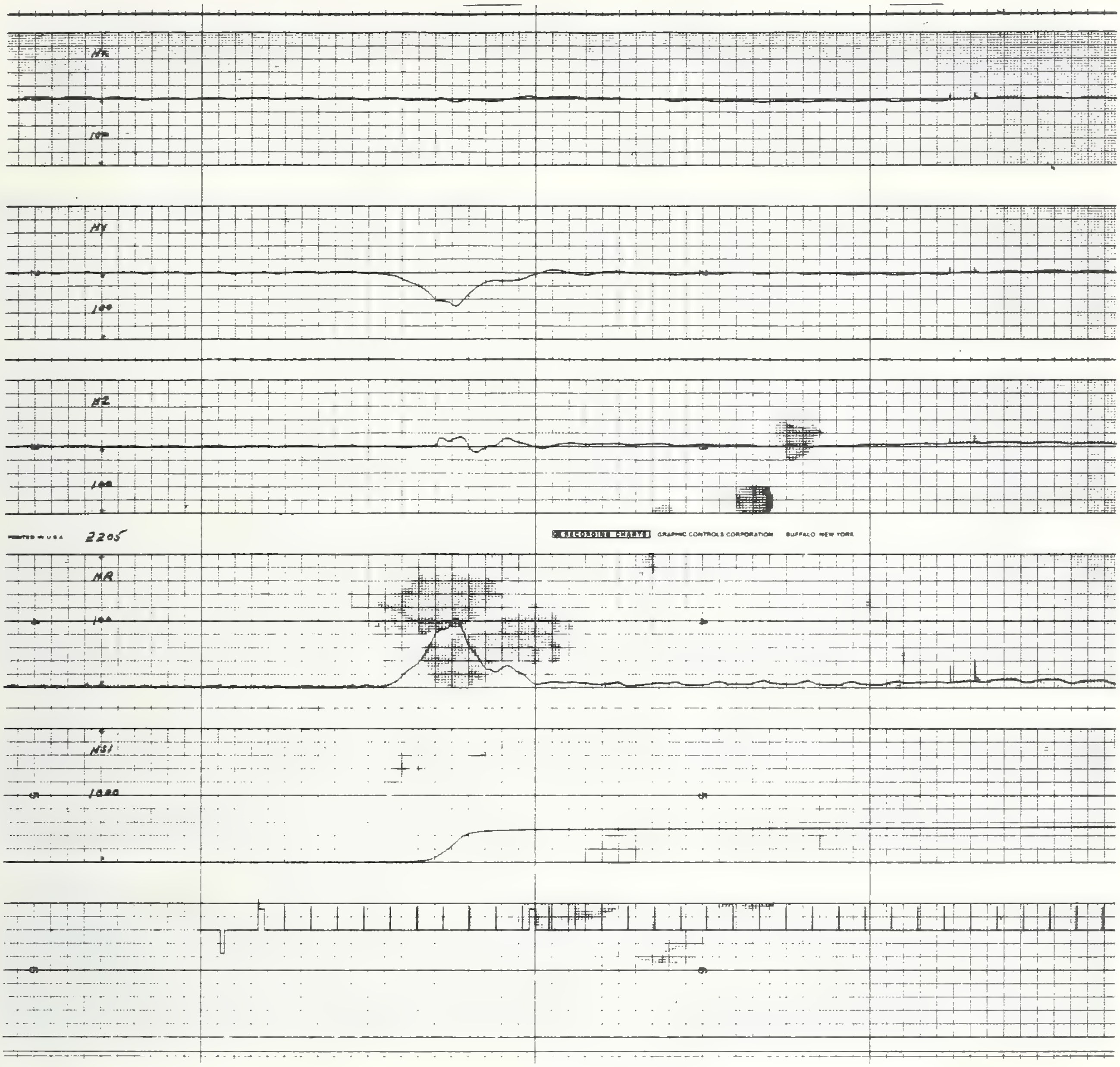


PRETEST

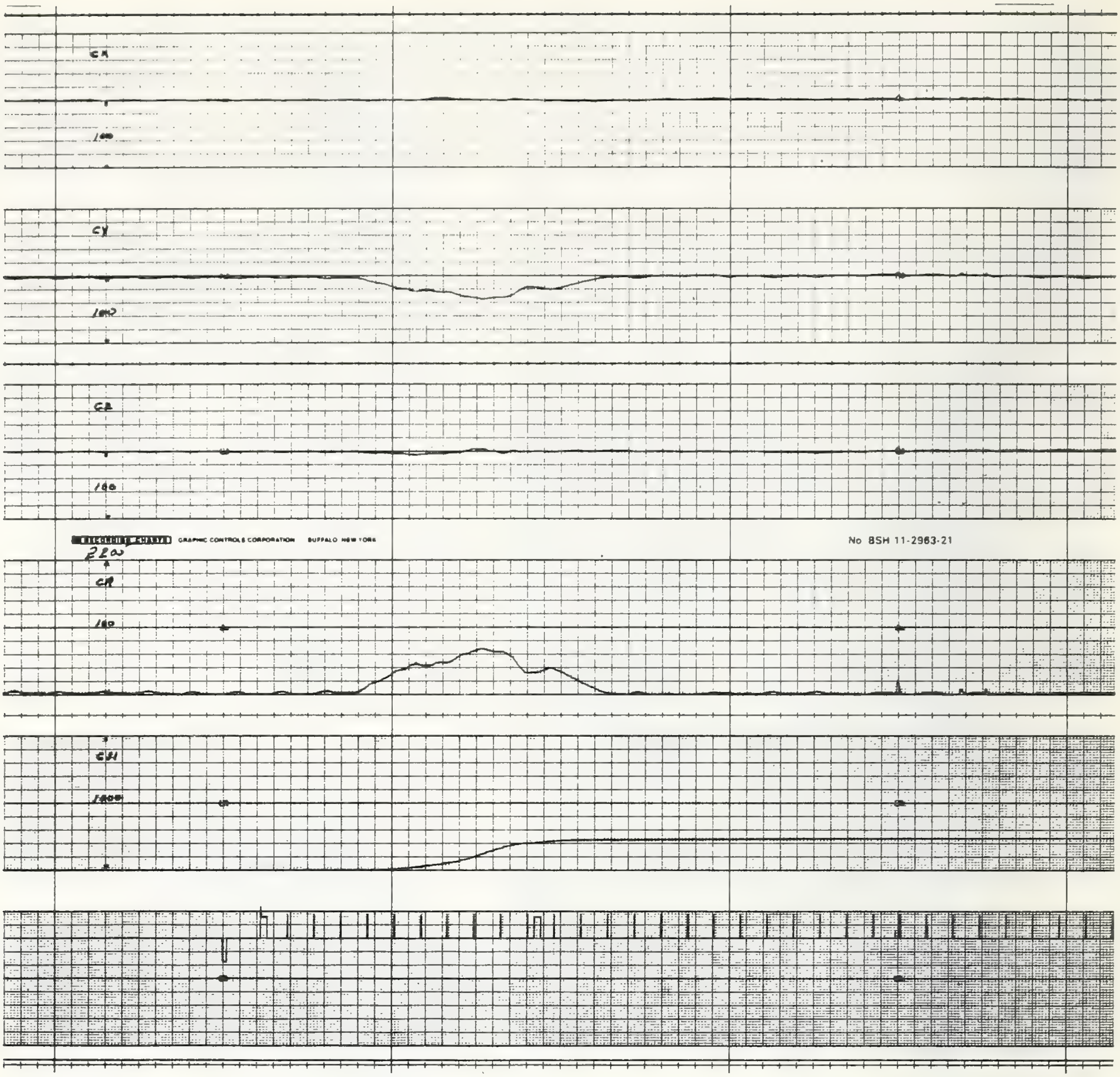


POST TEST

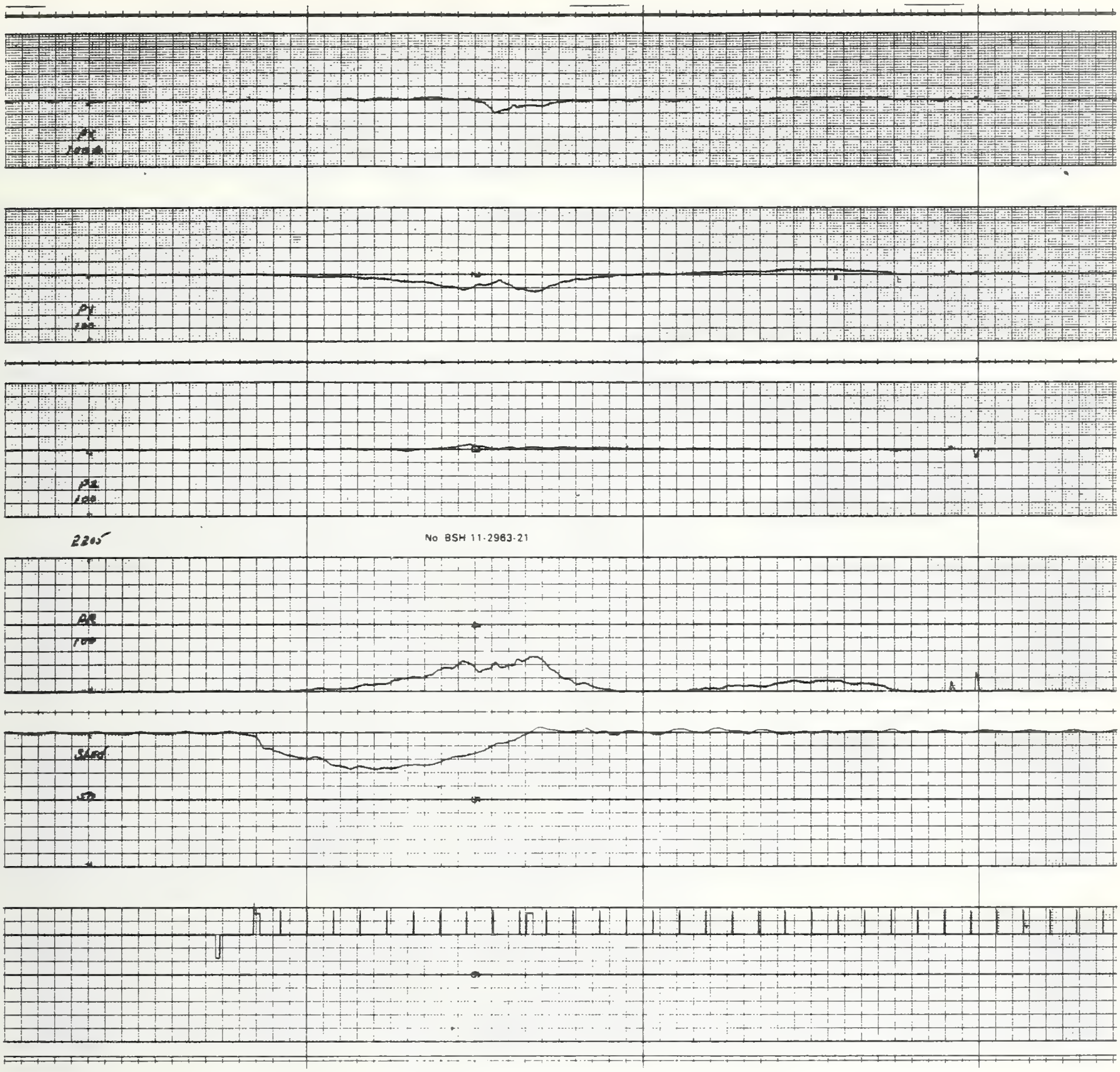
RUN 2205



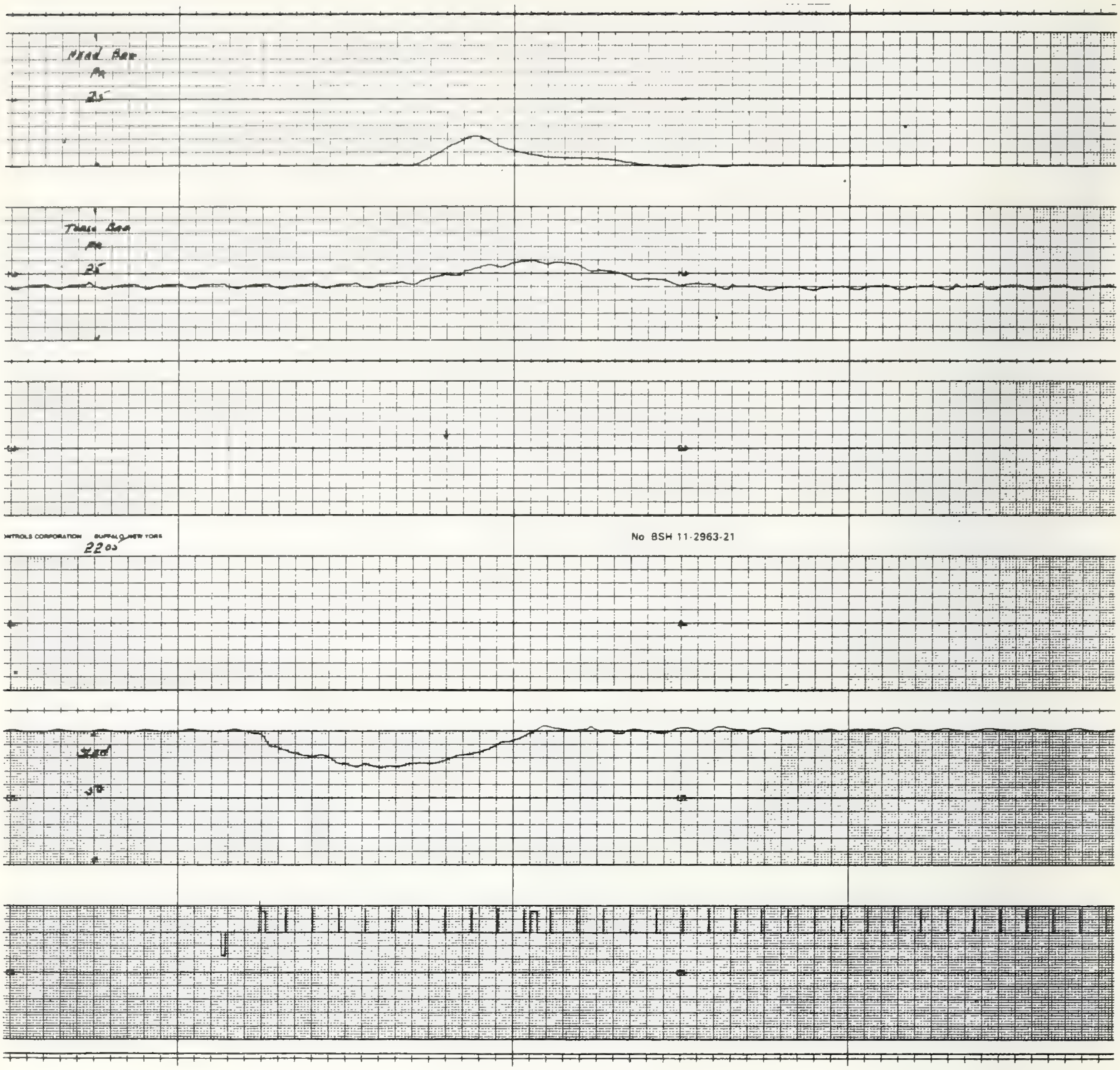
Time = 10 ms/division



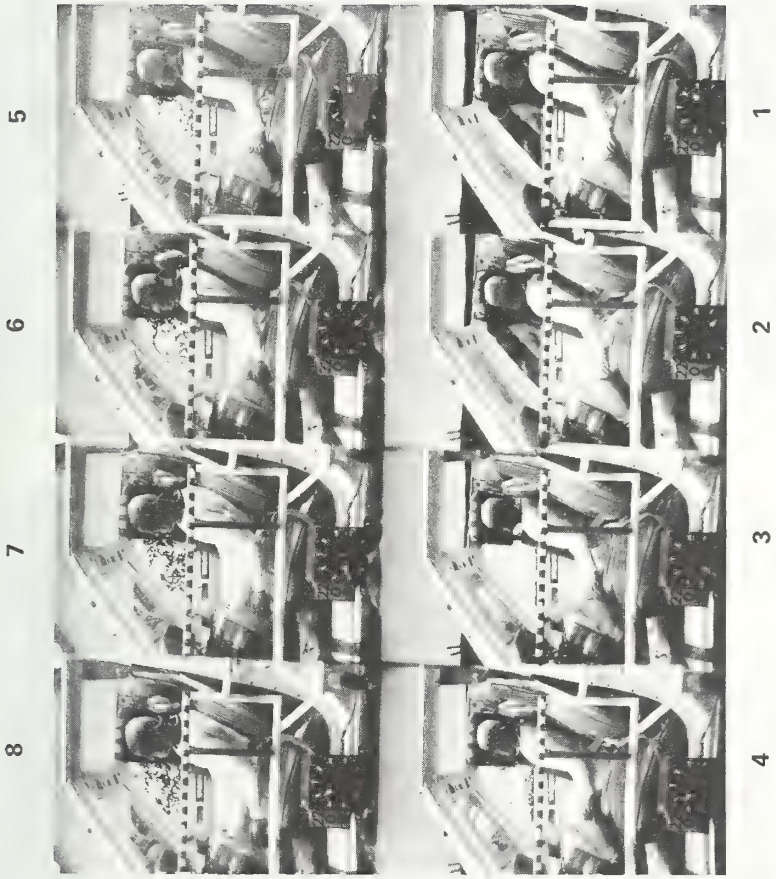
Time = 10 ms/division



Time = 10 ms/division

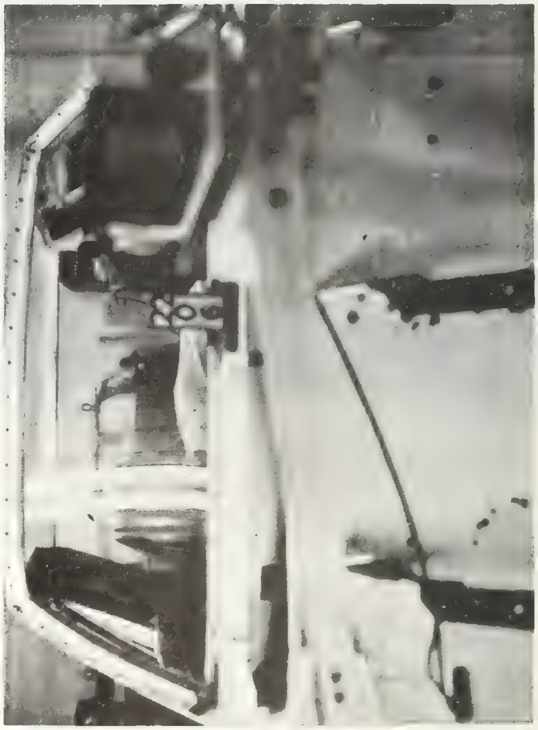


Time = 10 ms/division



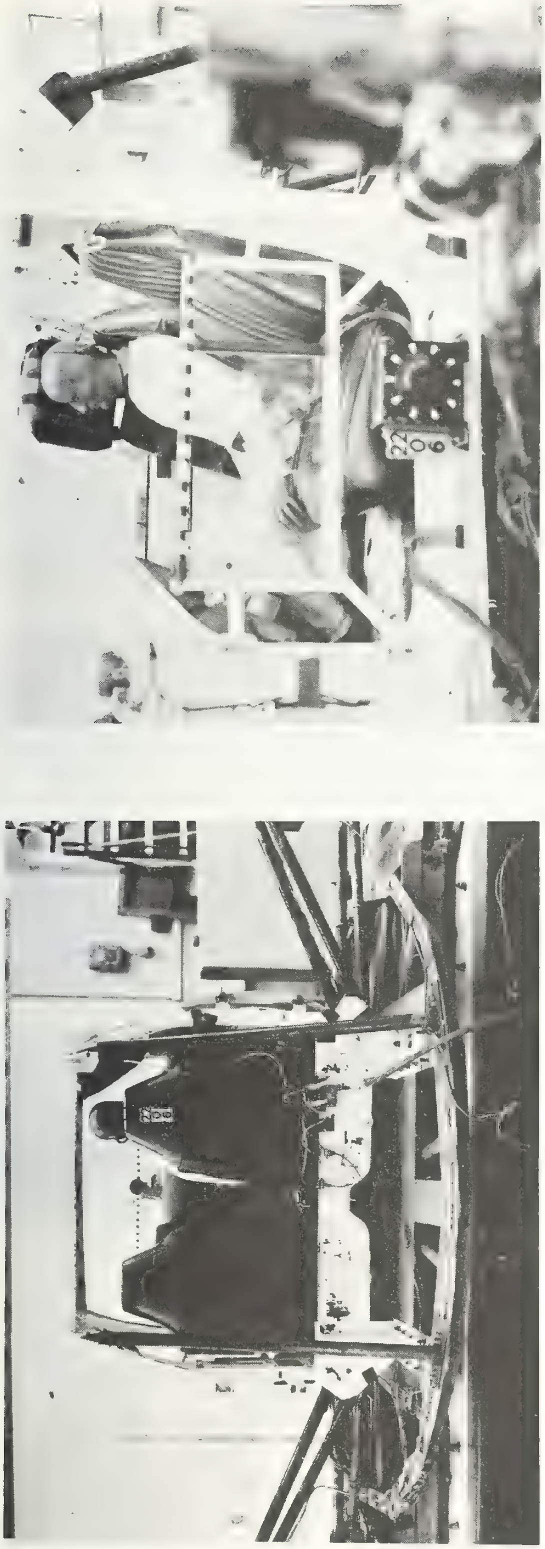
RUN 2206 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION


PRETEST

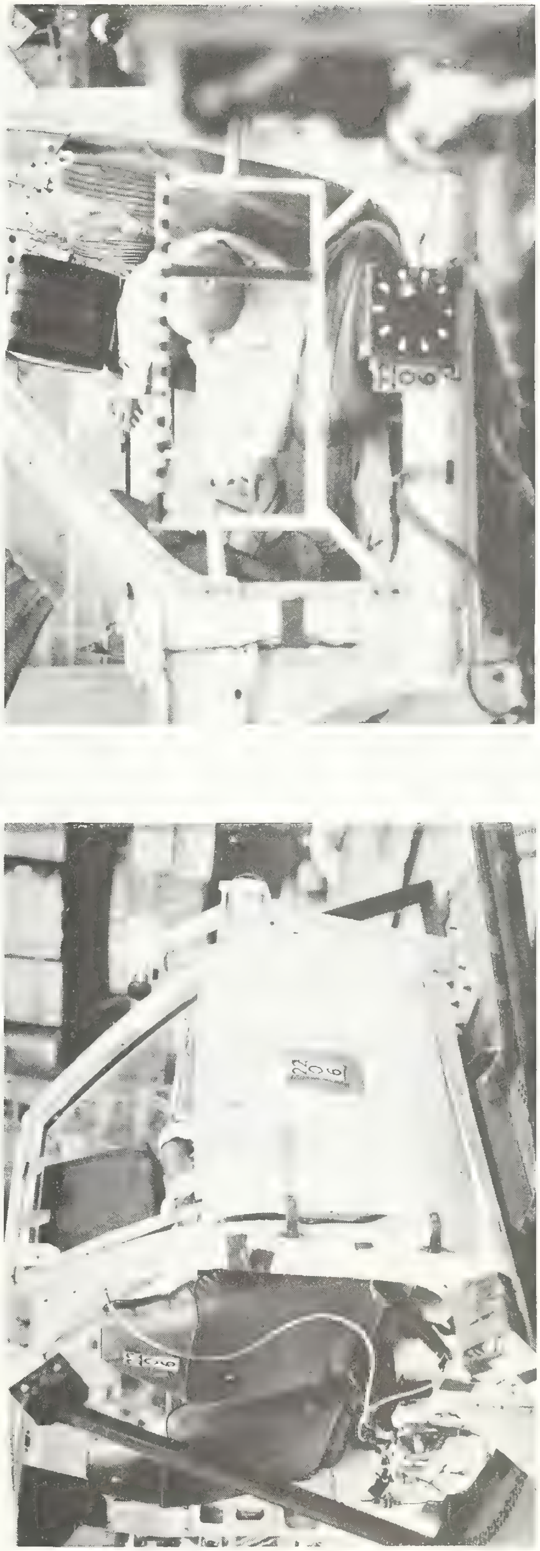


POST TEST

RUN 2206

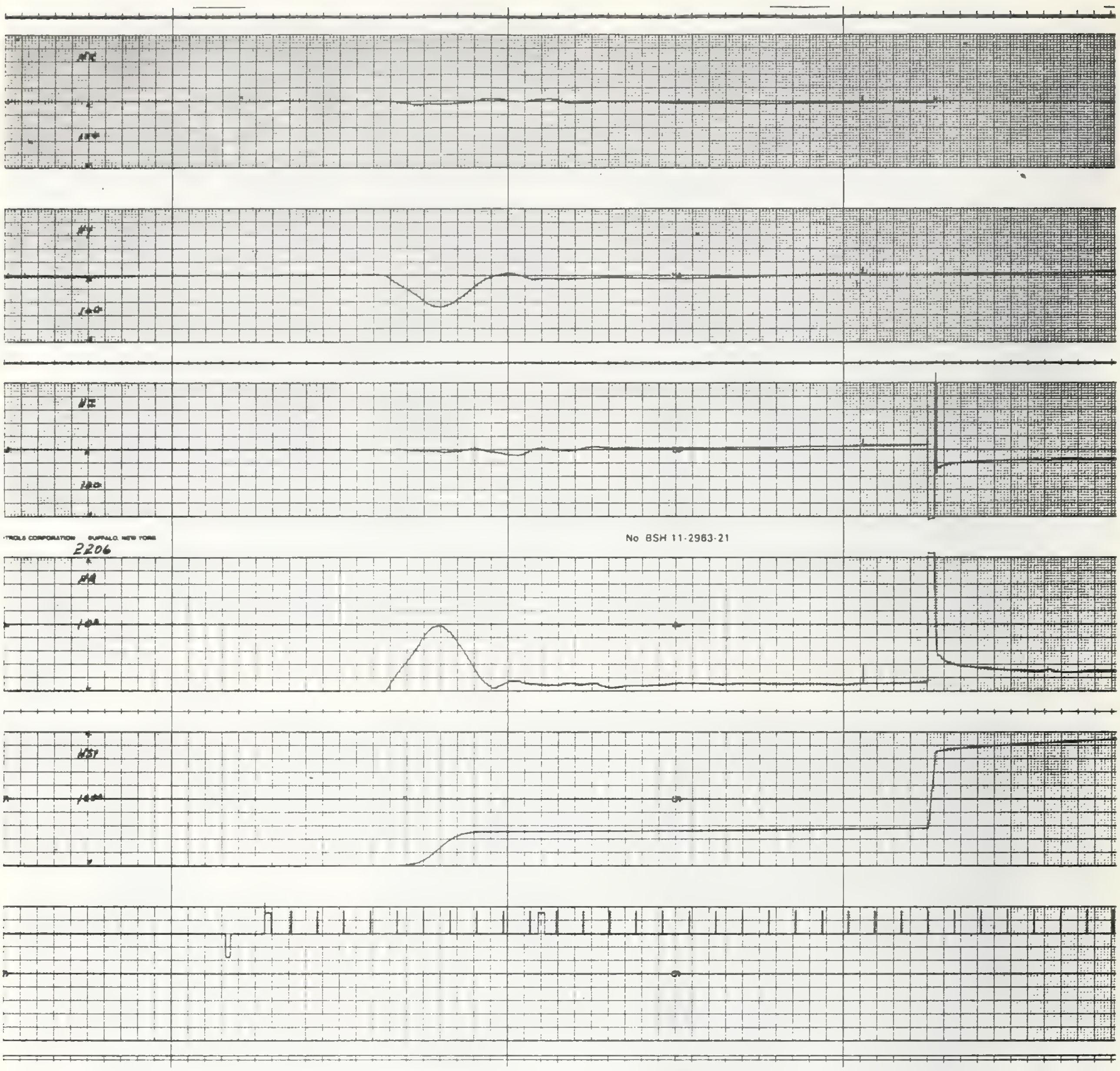


PRETEST

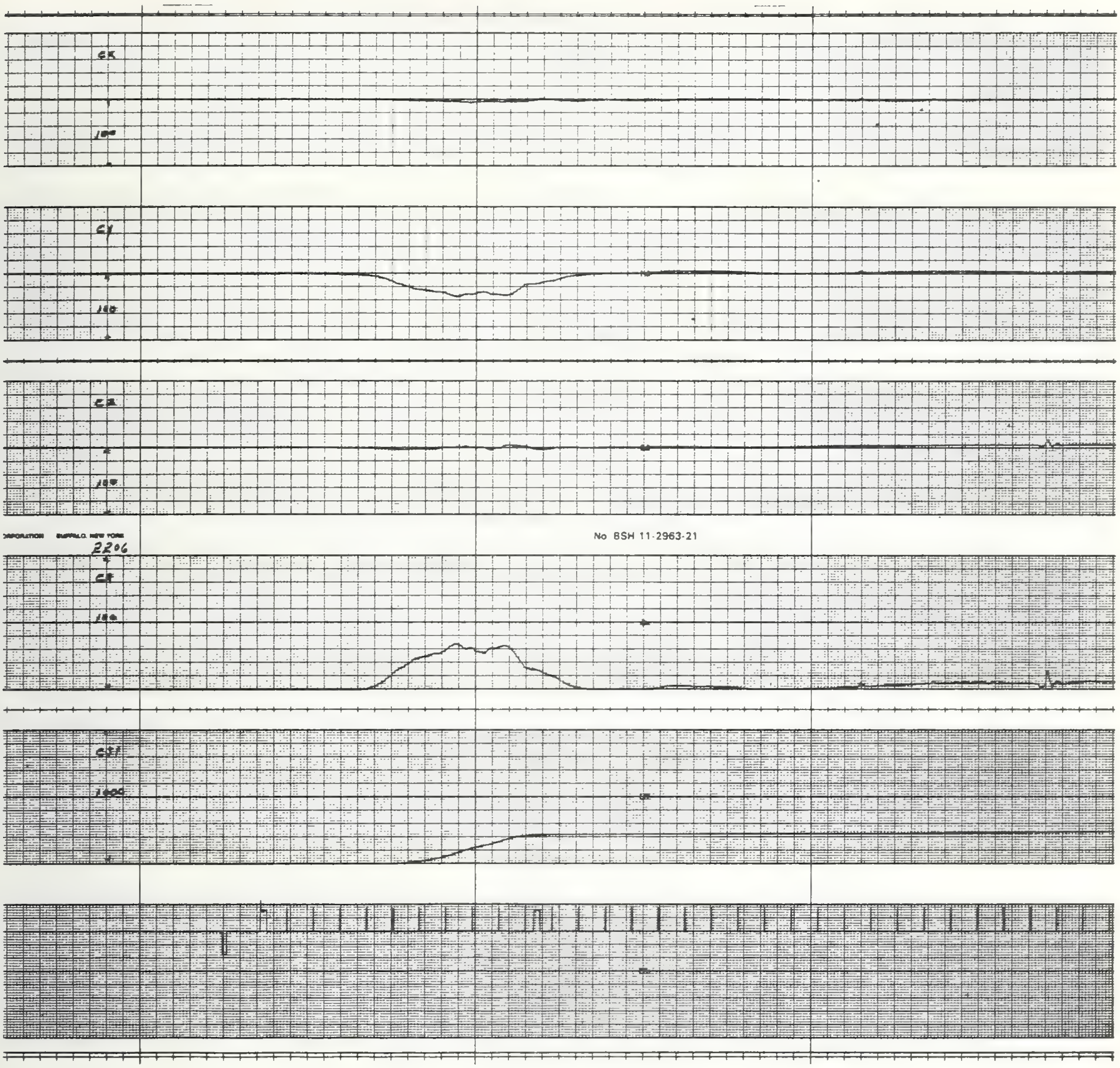


POST TEST

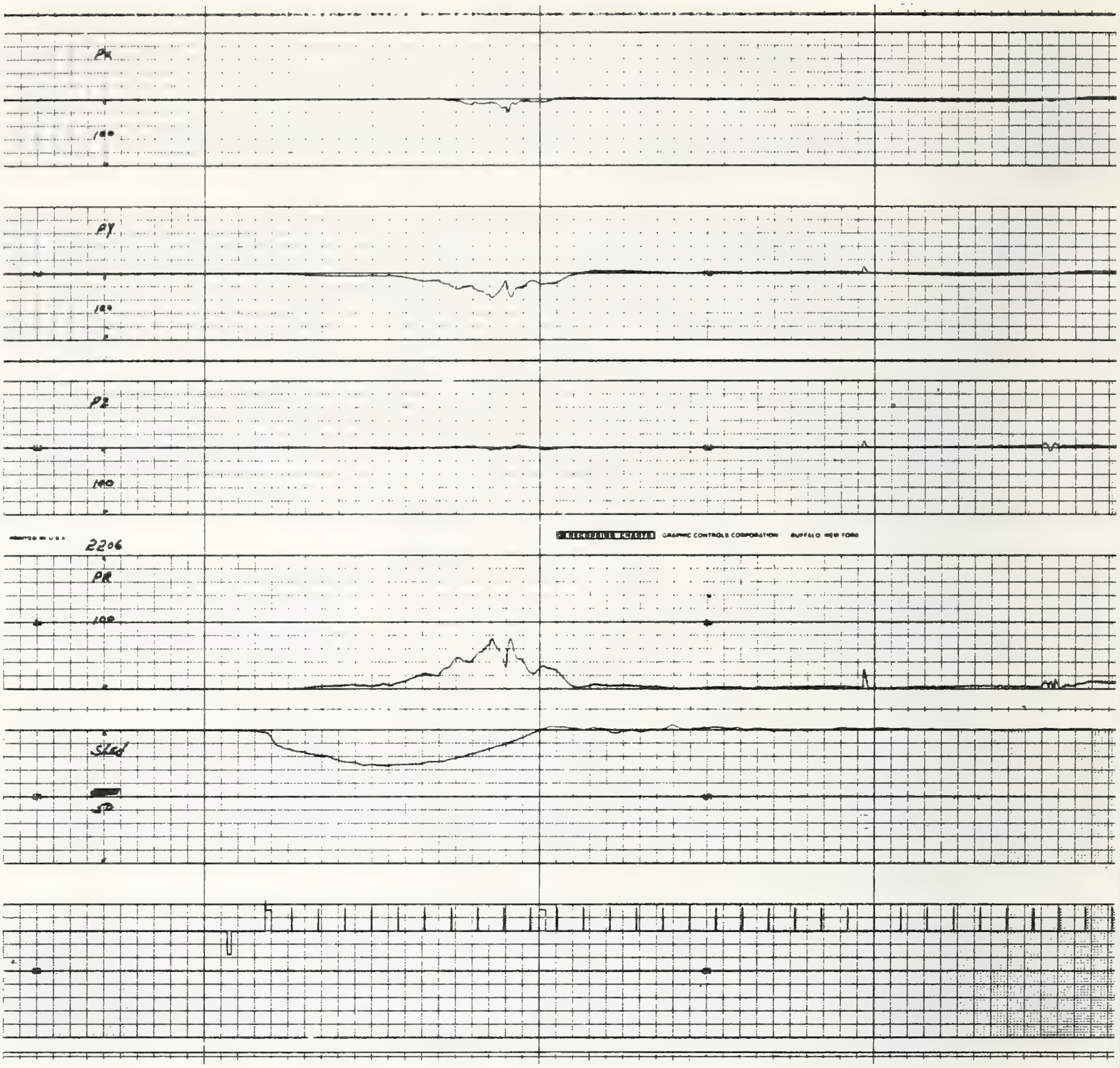
RUN 2206



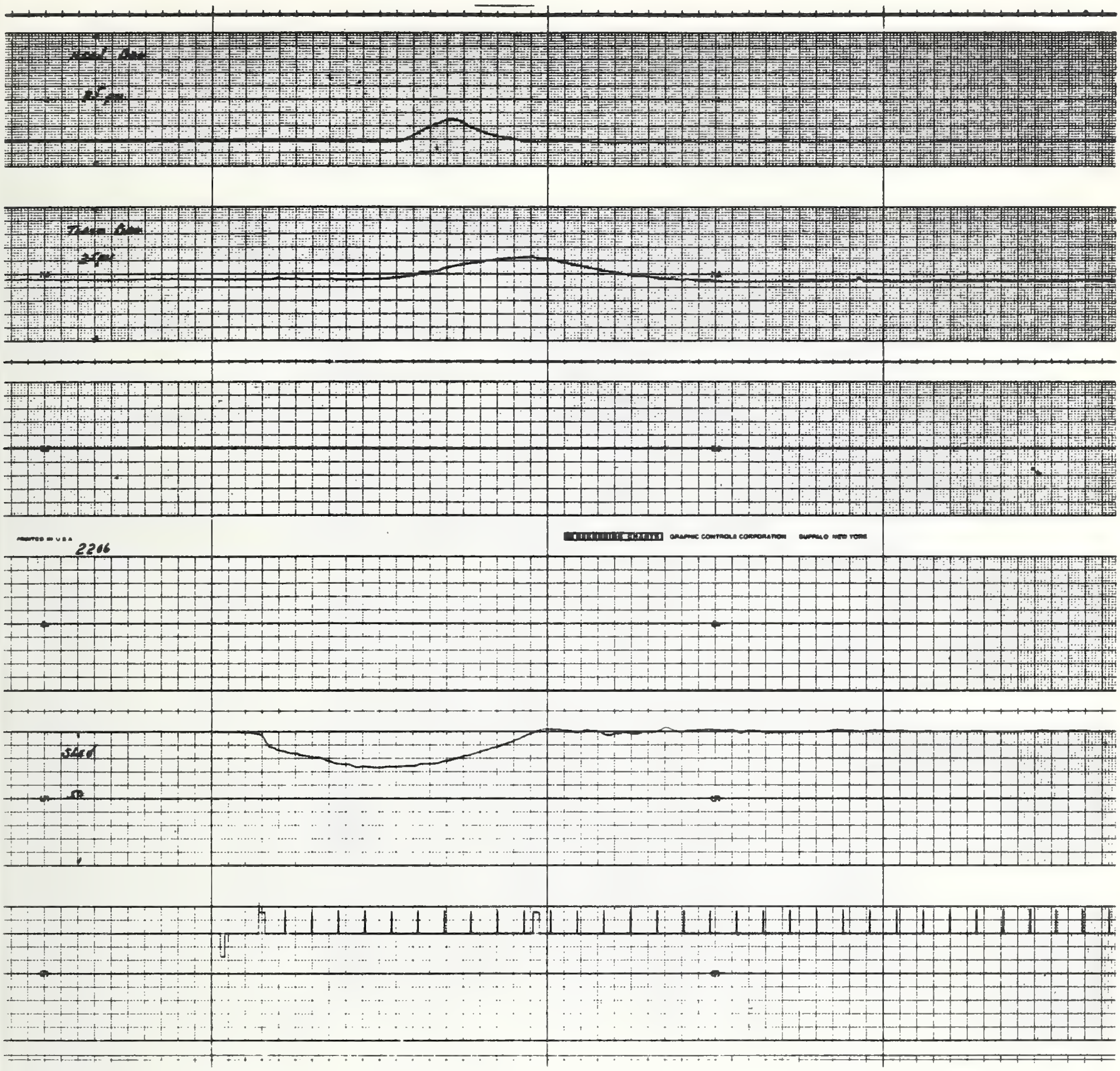
Time = 10 ms/division



Time = 10 ms/division



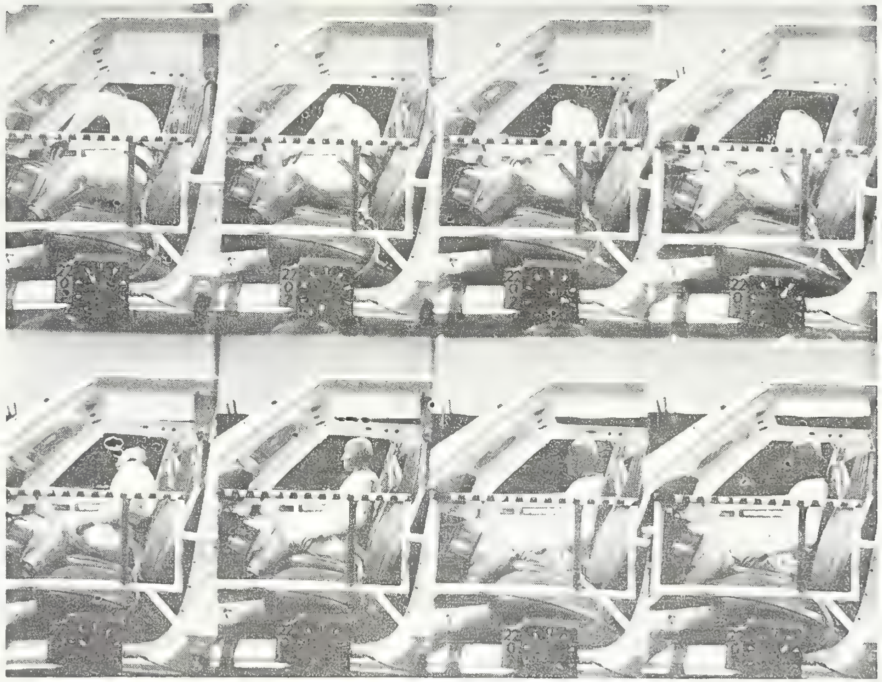
Time = 10 ms/division



Time = 10 ms/division

RUN 2207 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

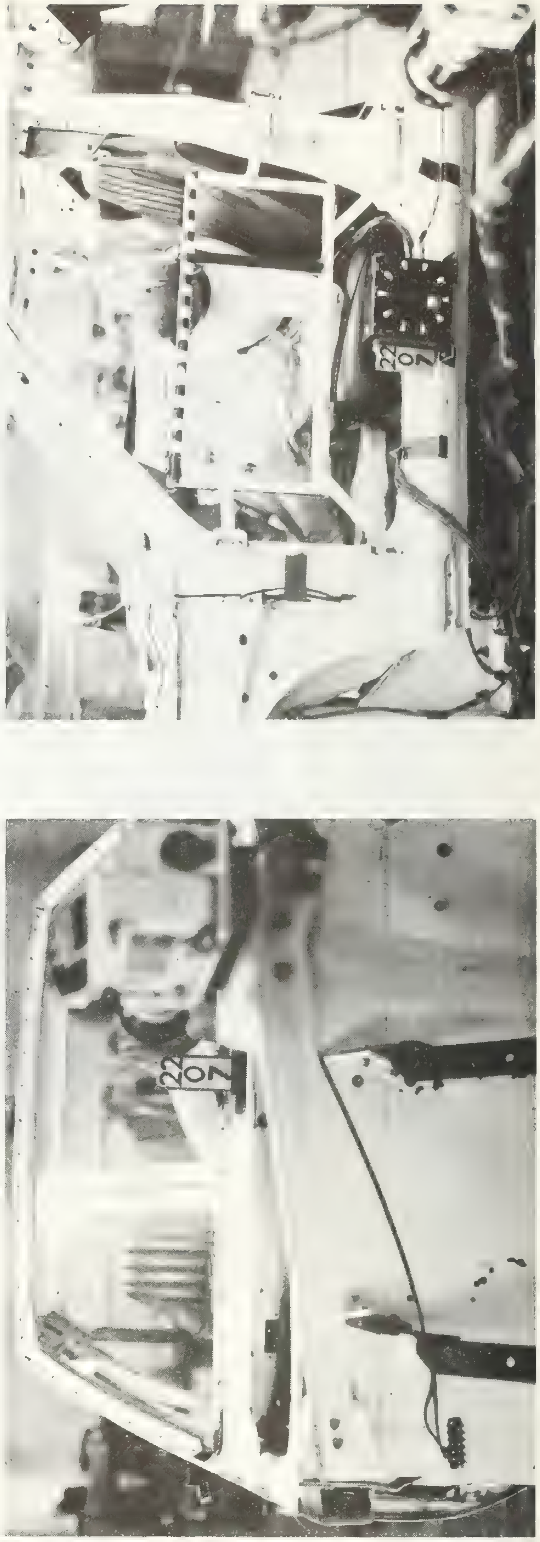
8 7 6 5



4 3 2 1

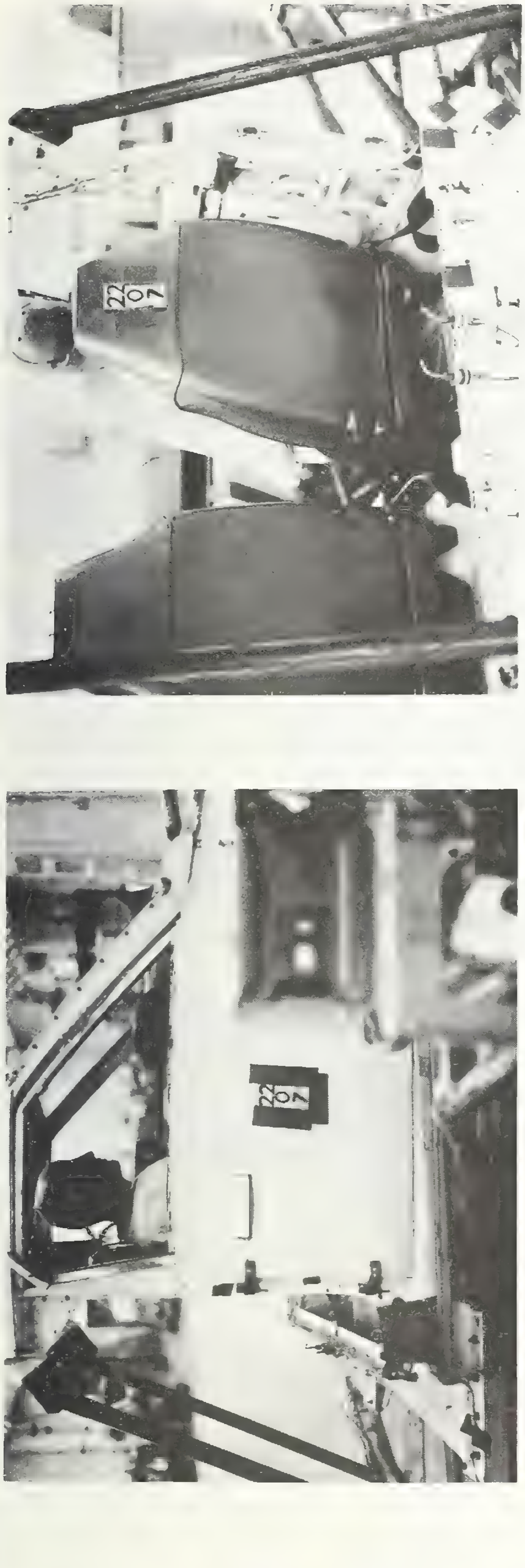
RUN 2207 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

PRETEST



POST TEST

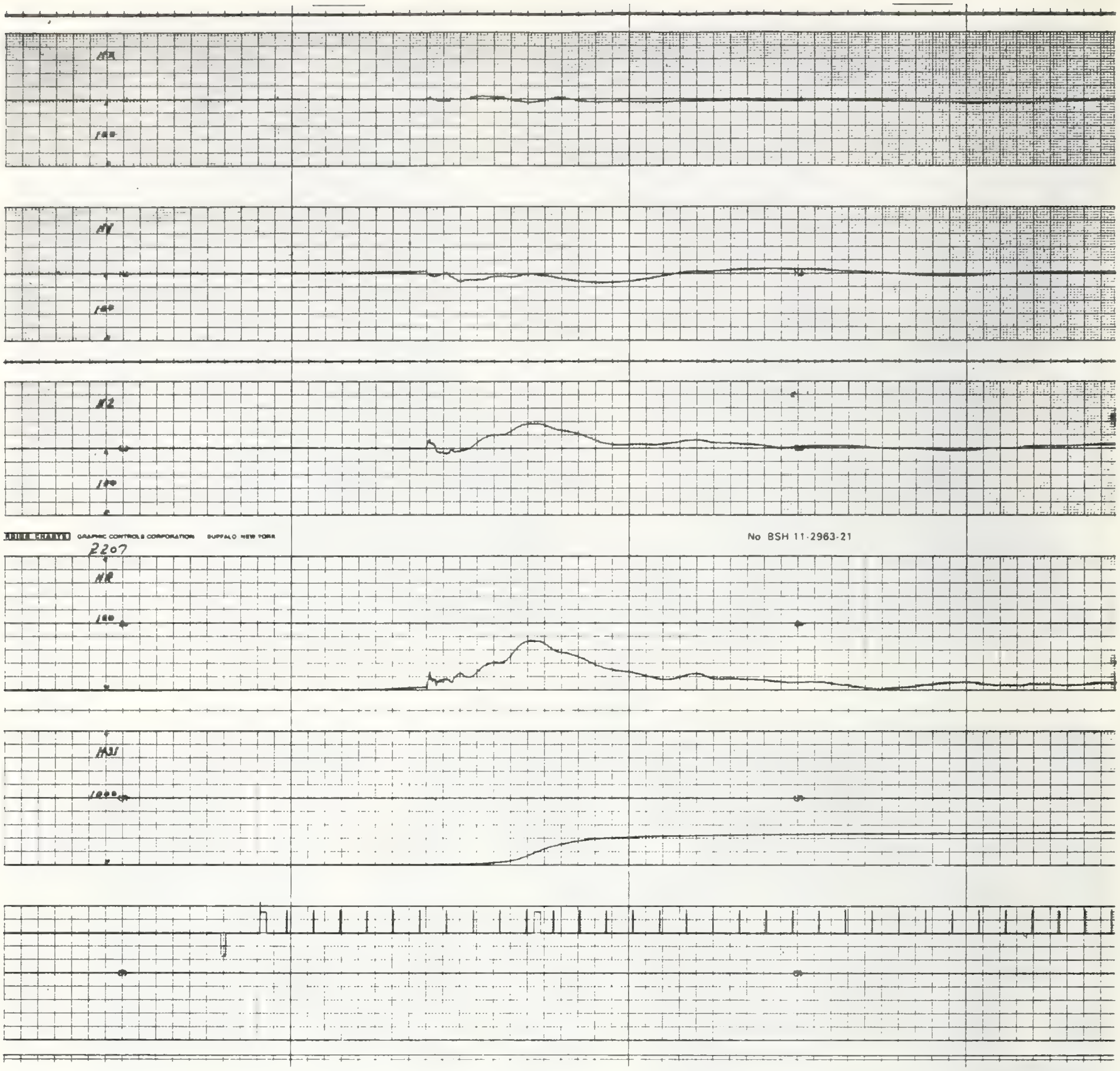
RUN 2207



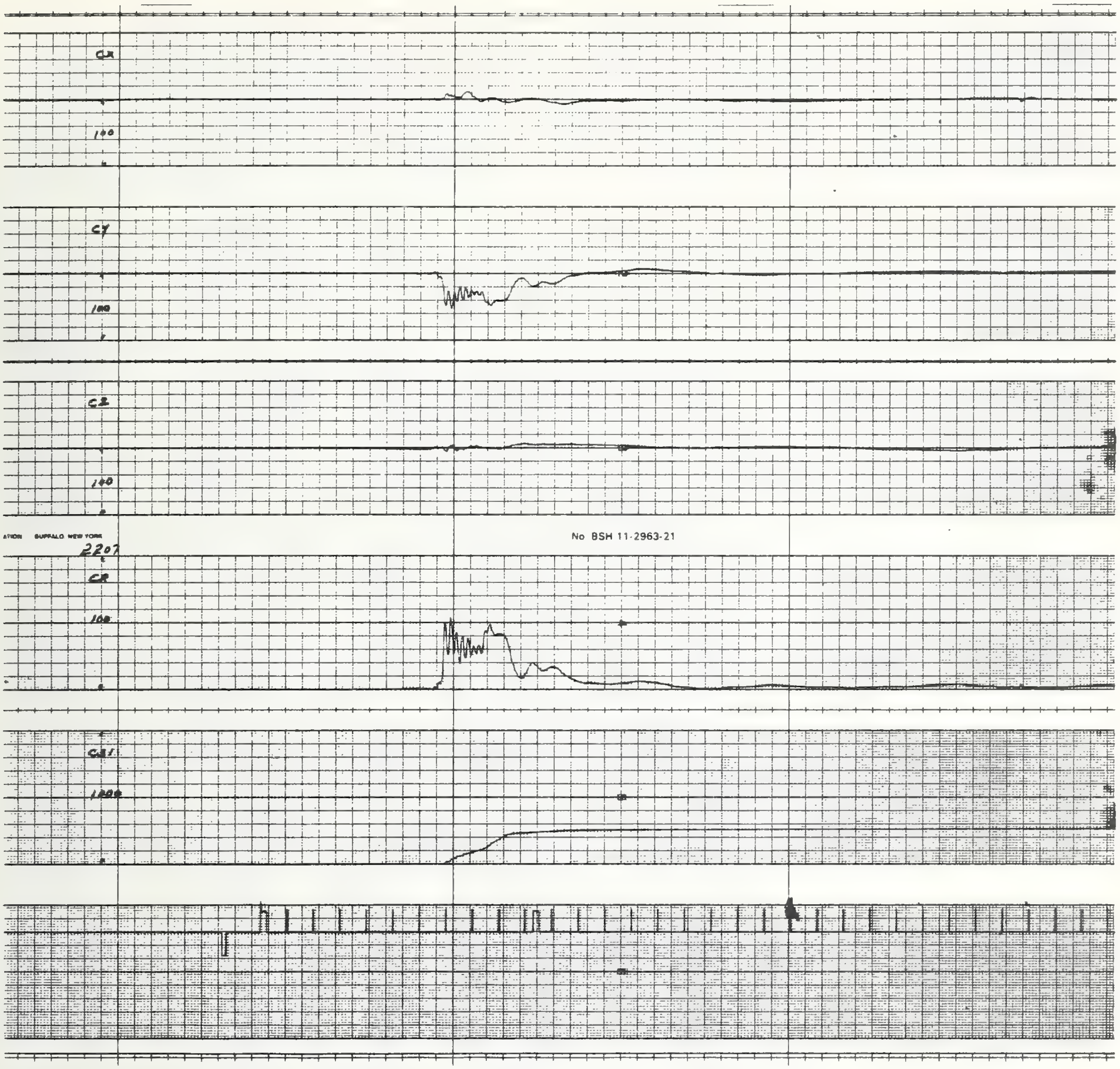
PRETEST

POST TEST

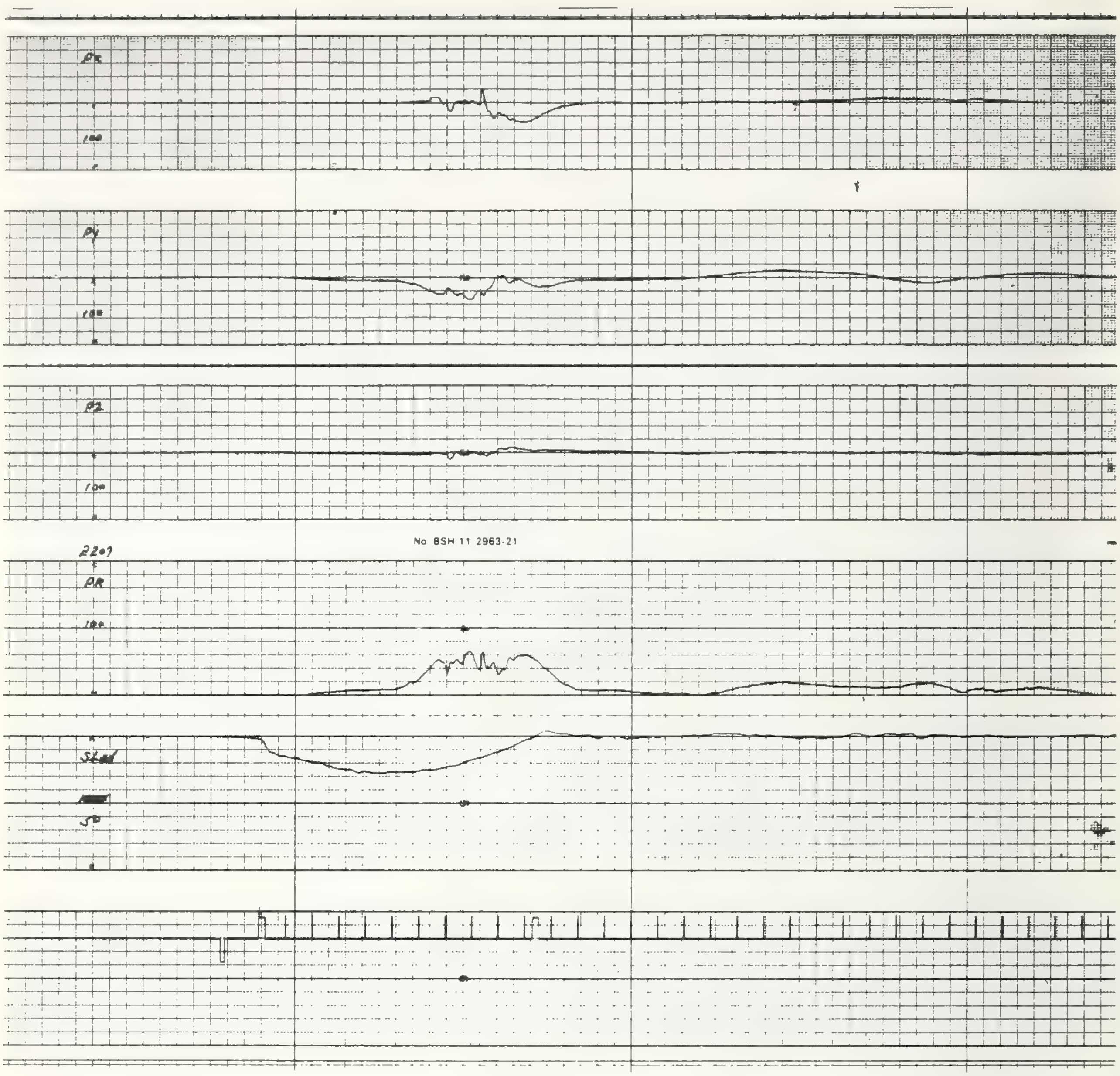
RUN 2207



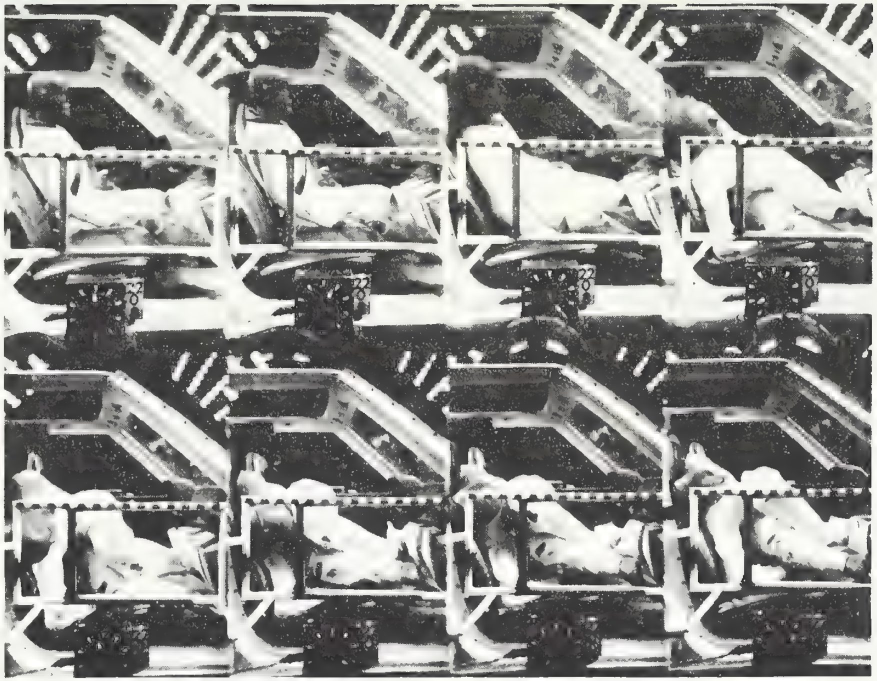
Time = 10 ms/division



Time = 10 ms/division

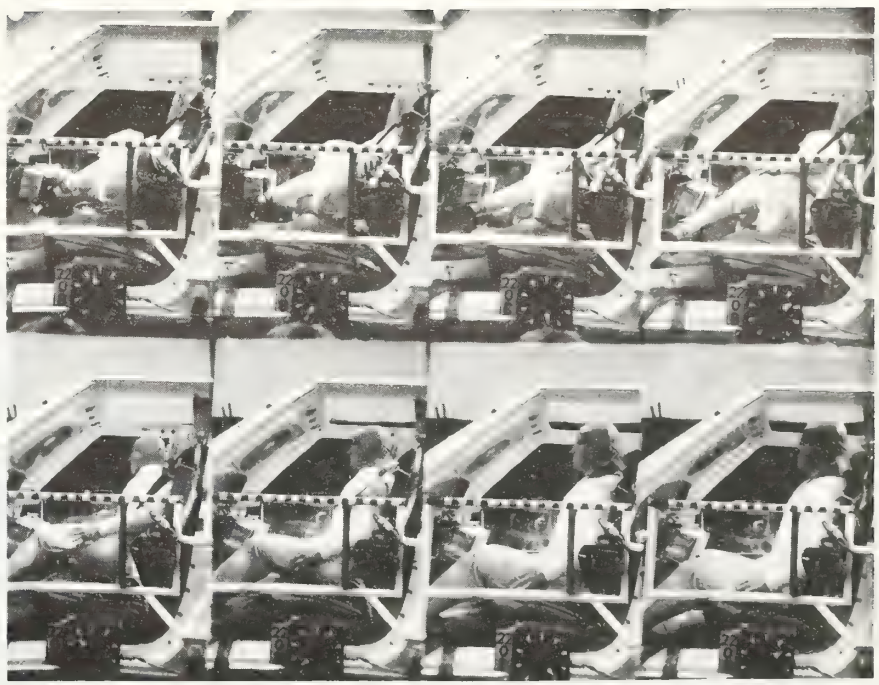


Time = 10 ms/division



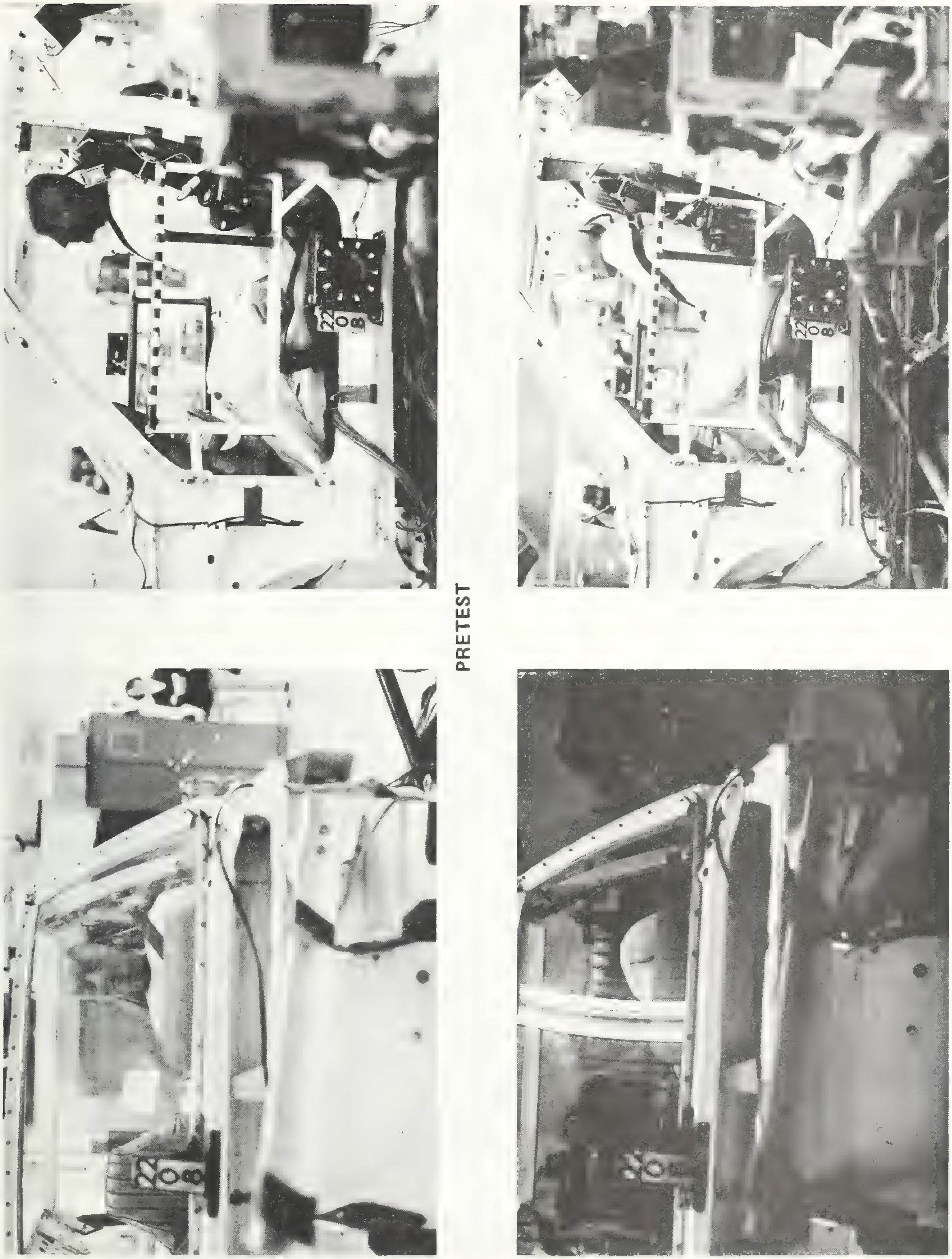
RUN 2208 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

8 7 6 5



4 3 2 1

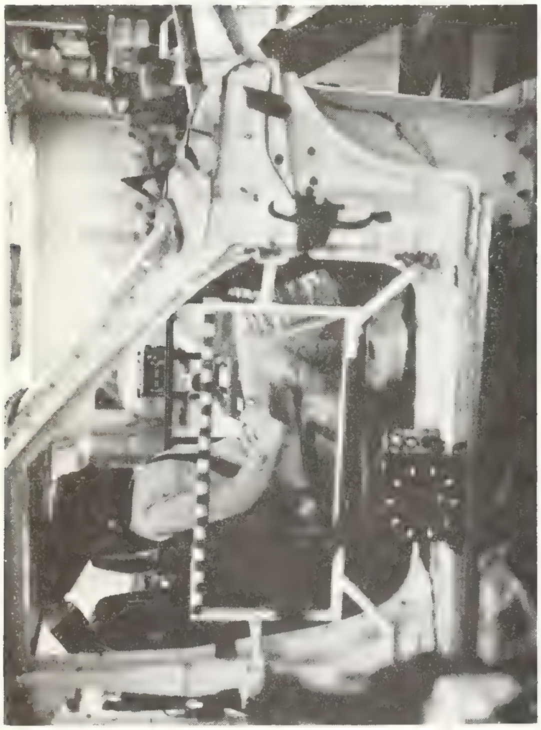
RUN 2208 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION



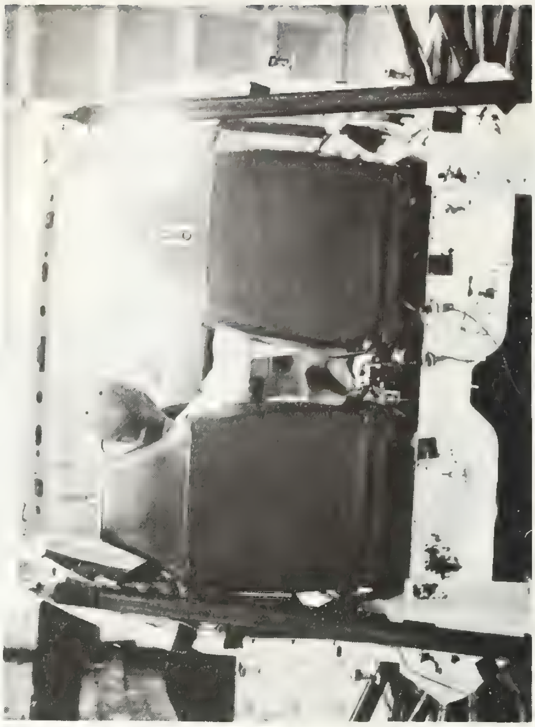
PRETEST

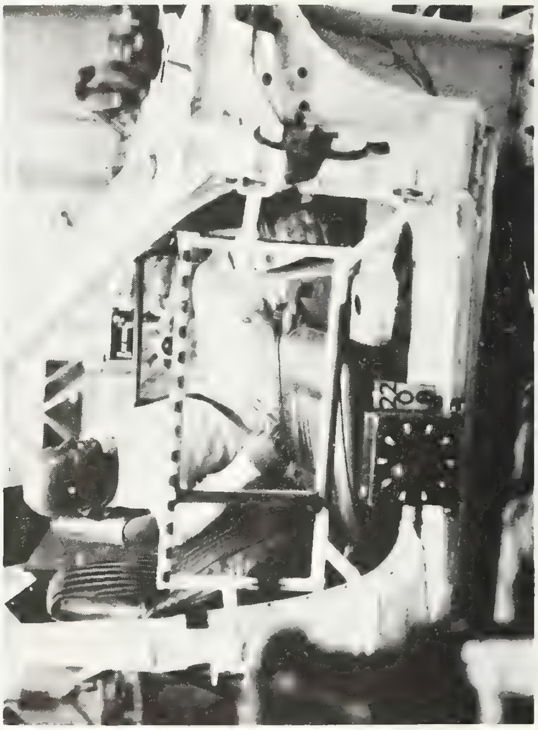
POST TEST

RUN 2208



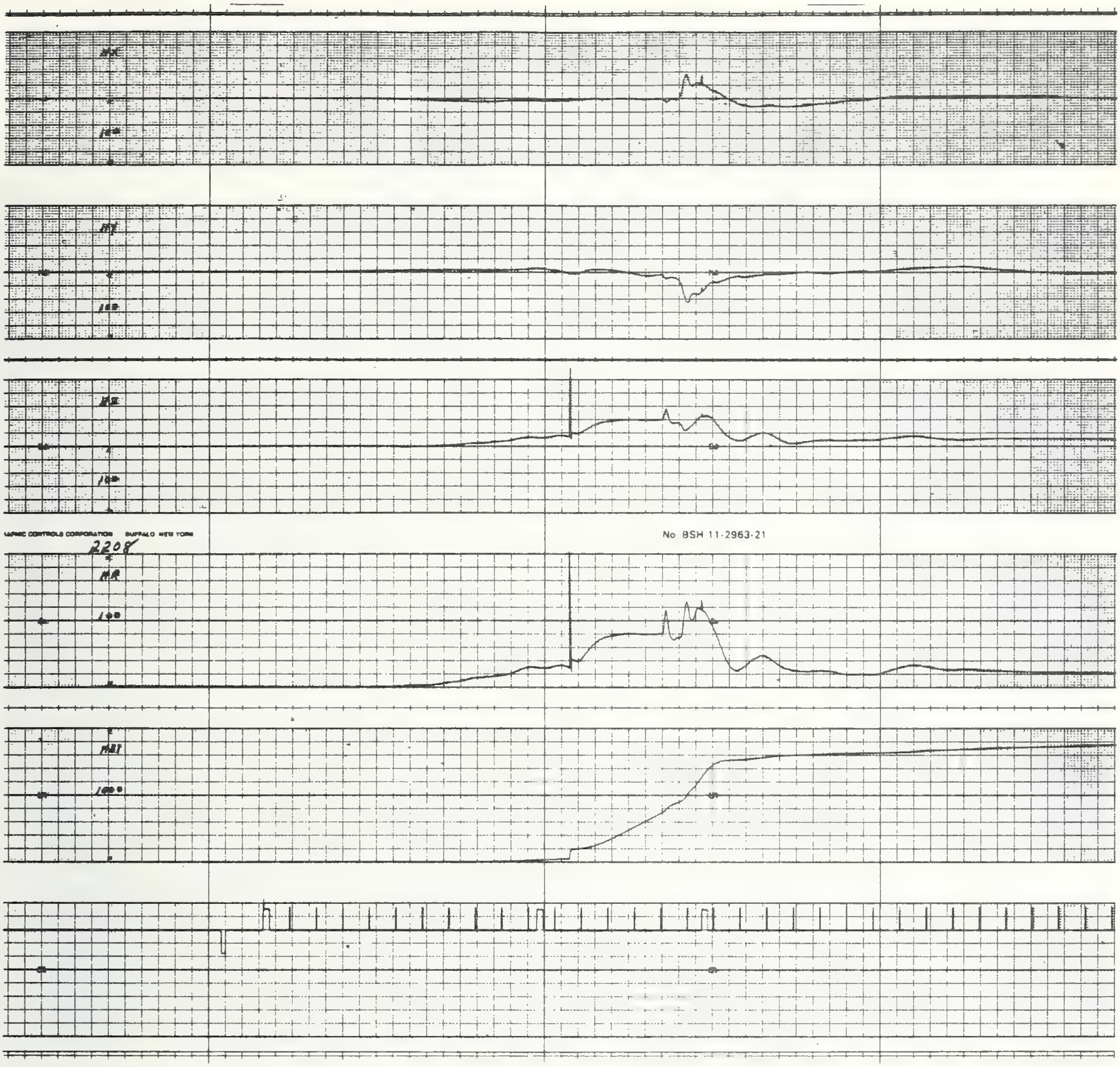
PRETEST



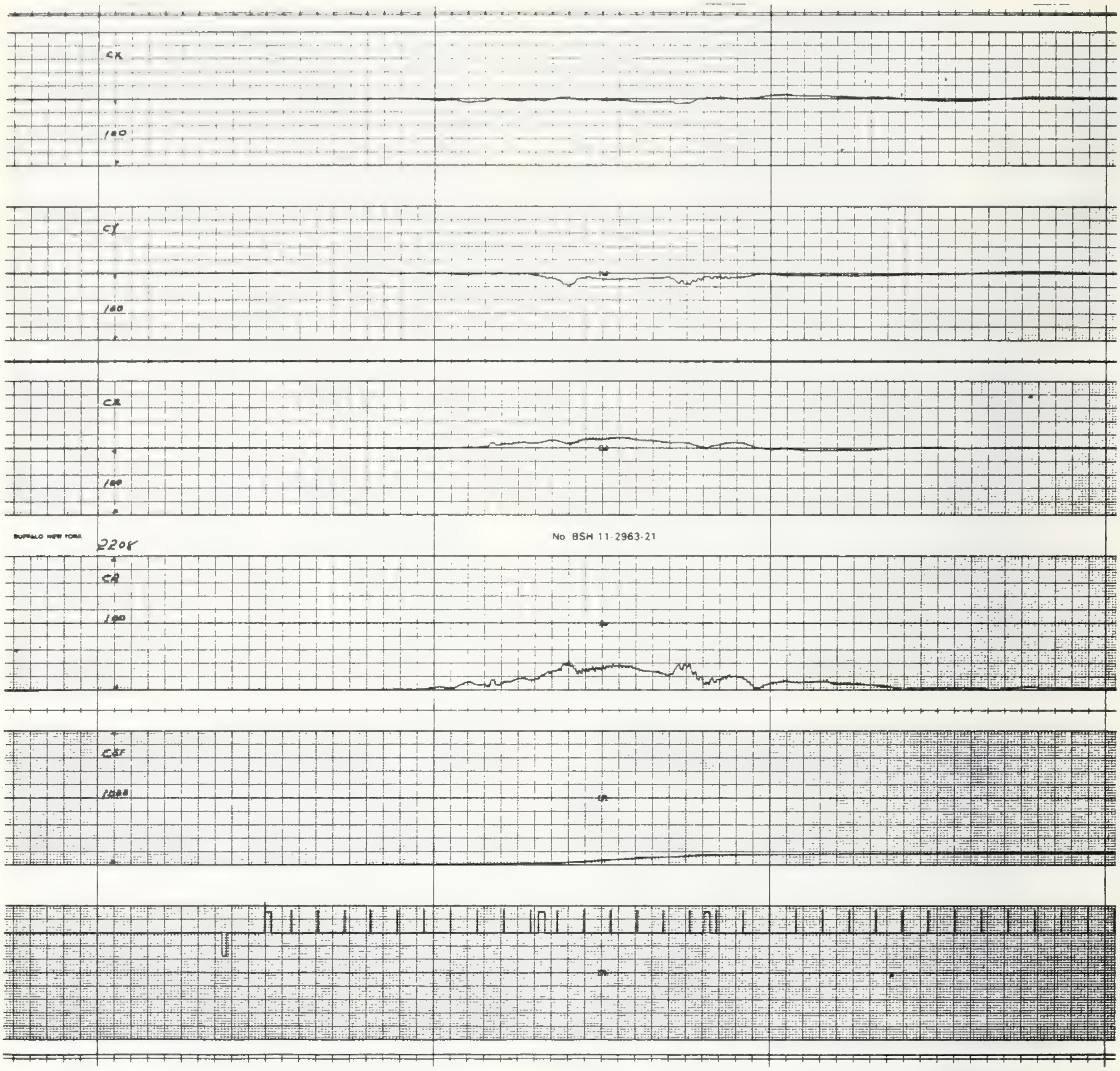


POST TEST

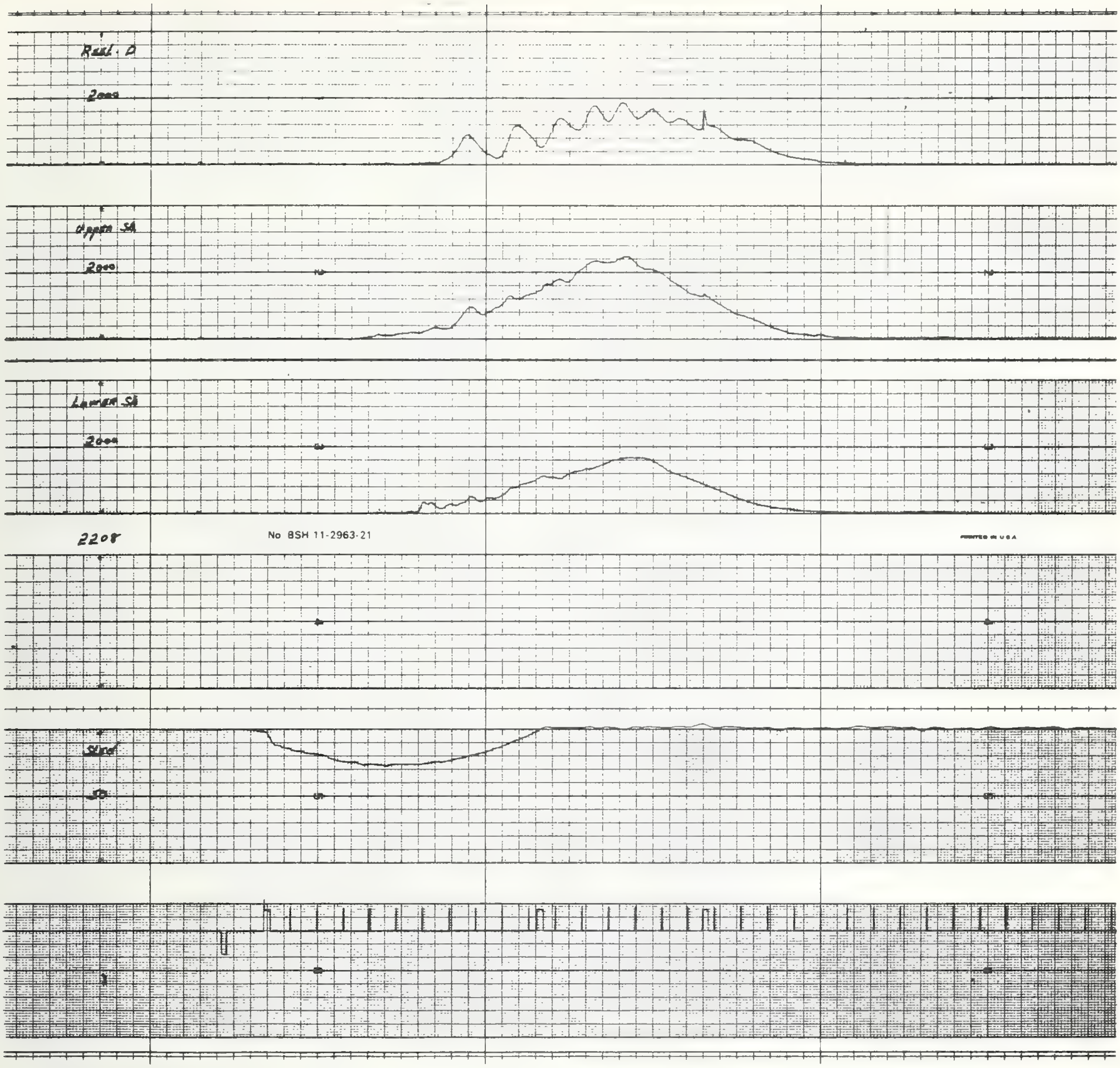
RUN 2208



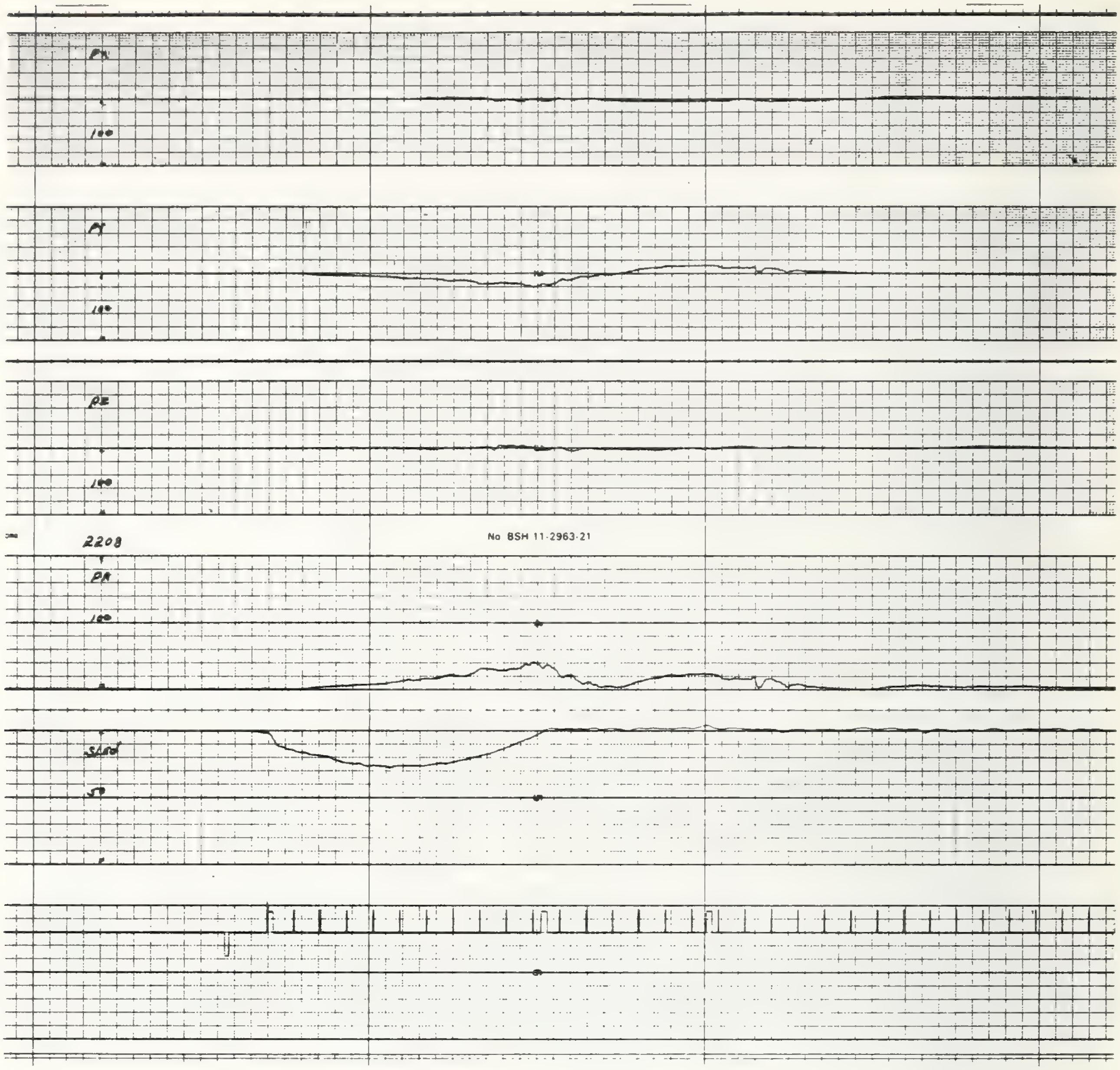
Time = 10 ms/division



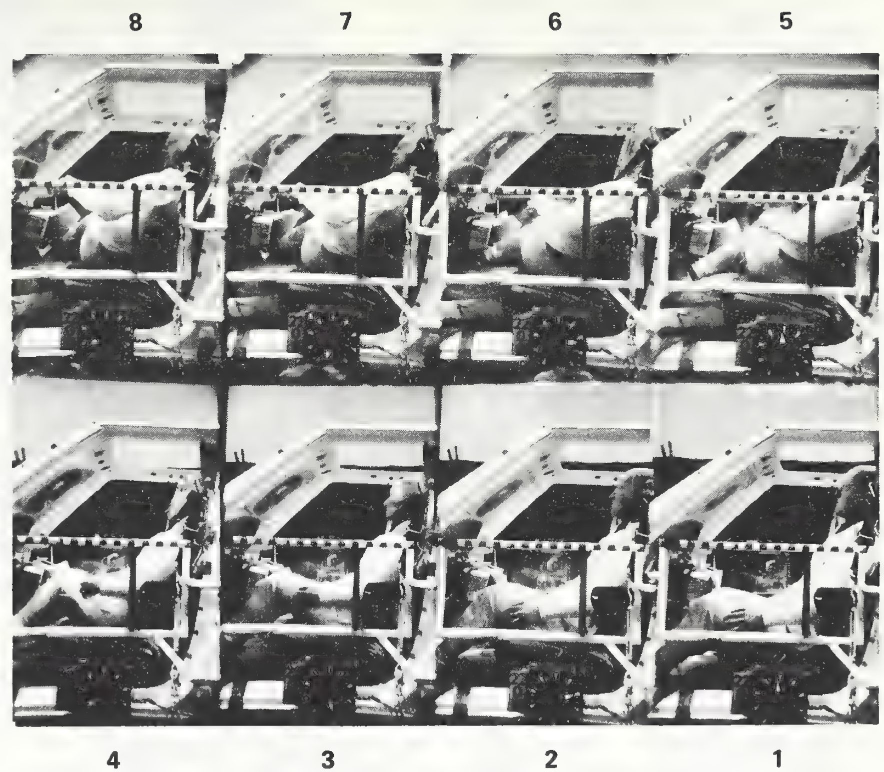
Time = 10 ms/division



Time = 10 ms/division

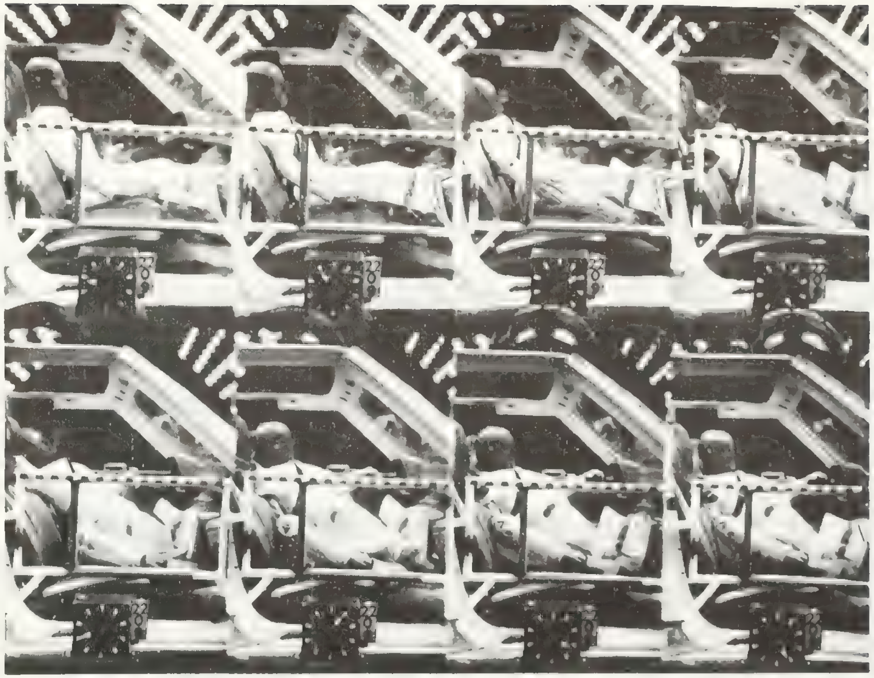


Time = 10 ms/division



RUN 2209 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

1 2 3 4



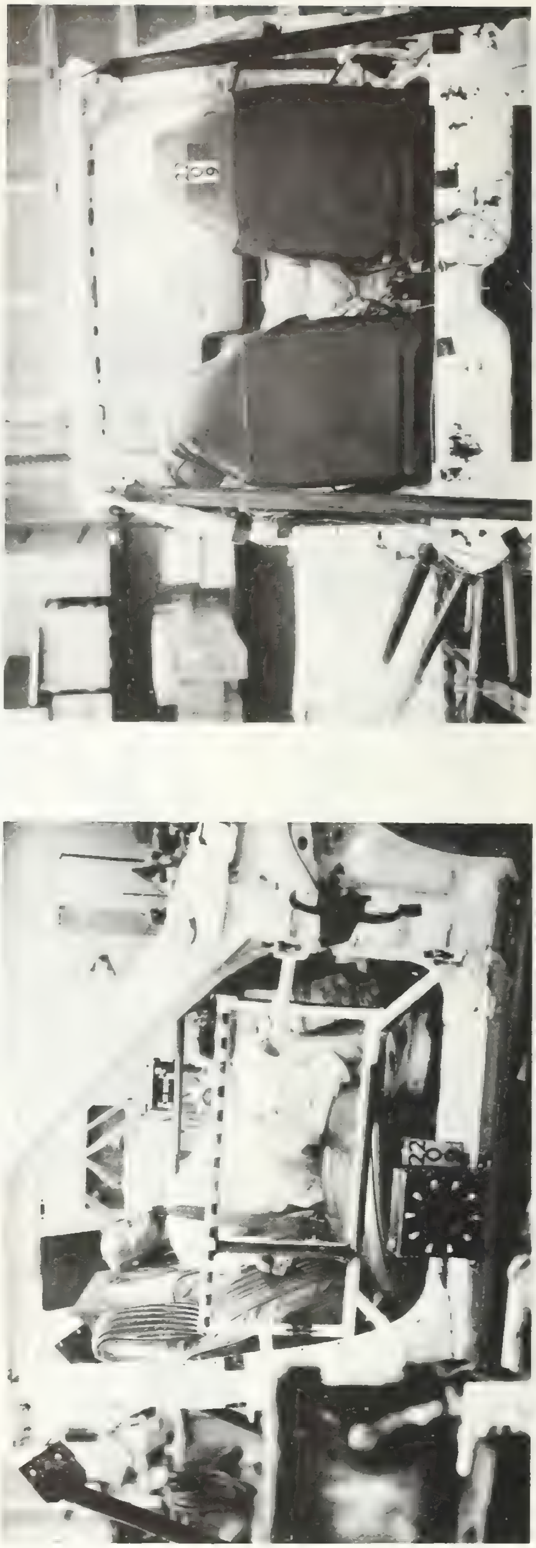
5 6 7 8

RUN 2209 SEQUENCE CAMERA
CLOCK = 10 MS/DIVISION

PRETEST

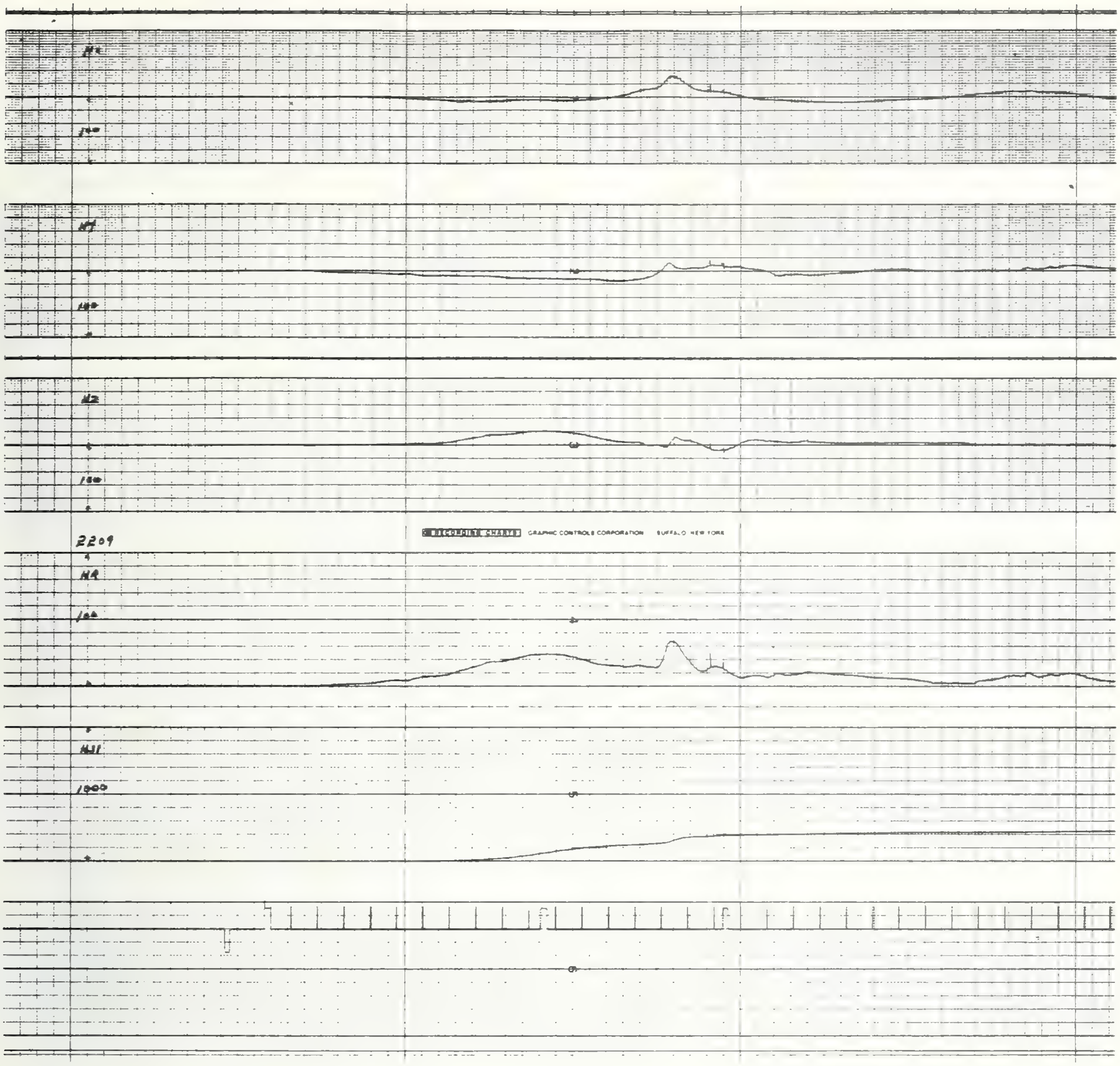
POST TEST
RUN 2209

PRETEST

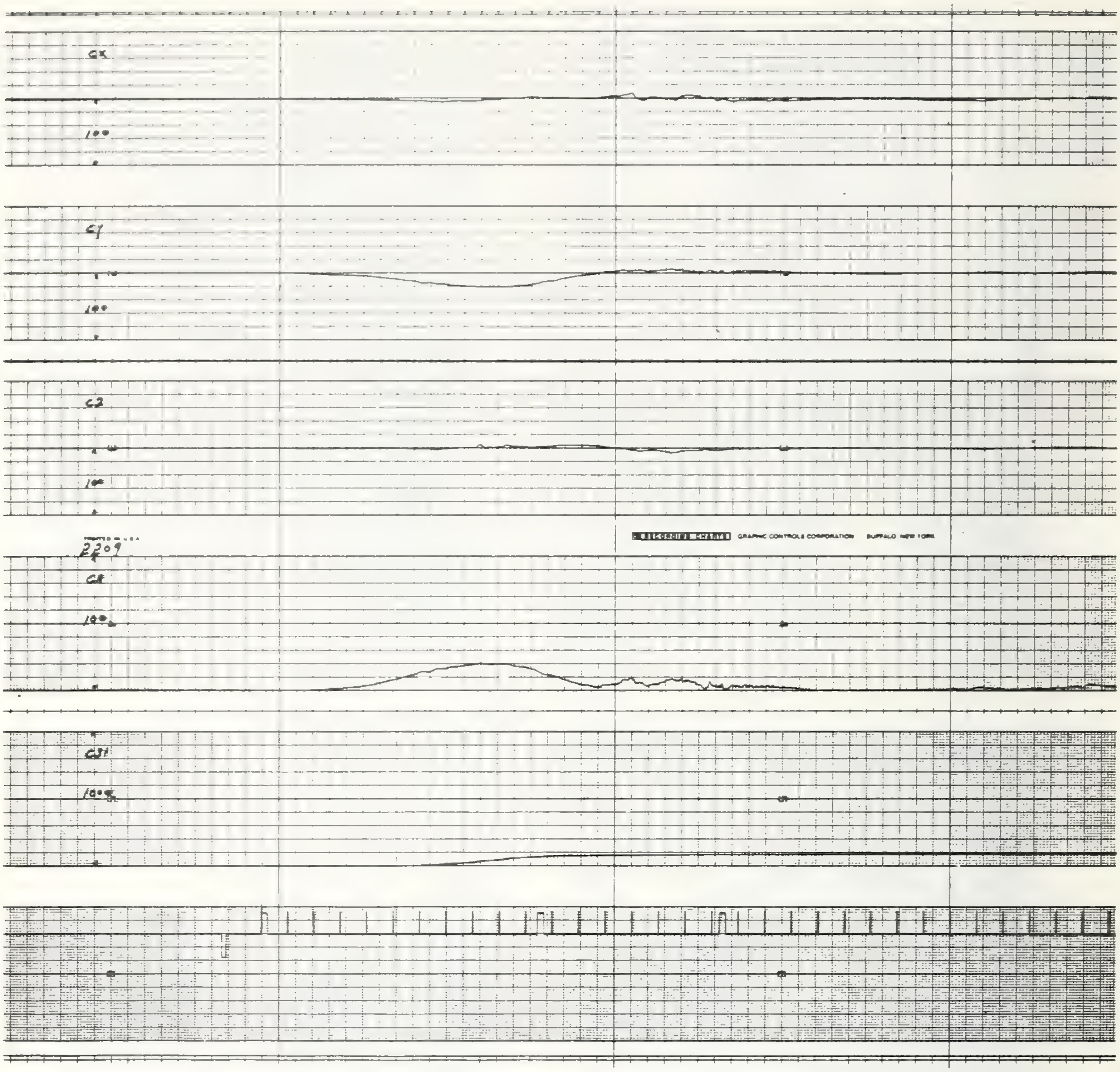


POST TEST

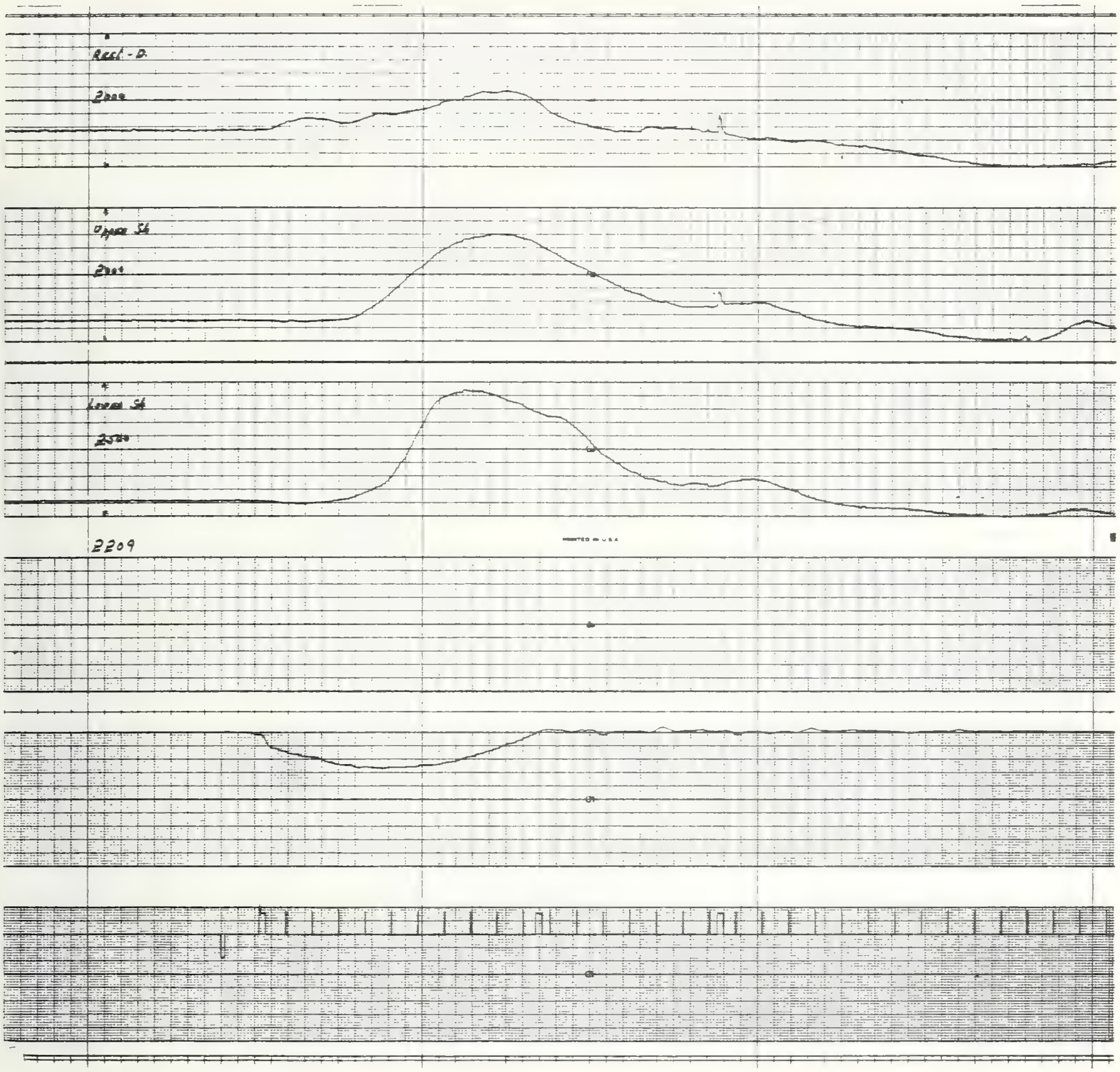
RUN 2209



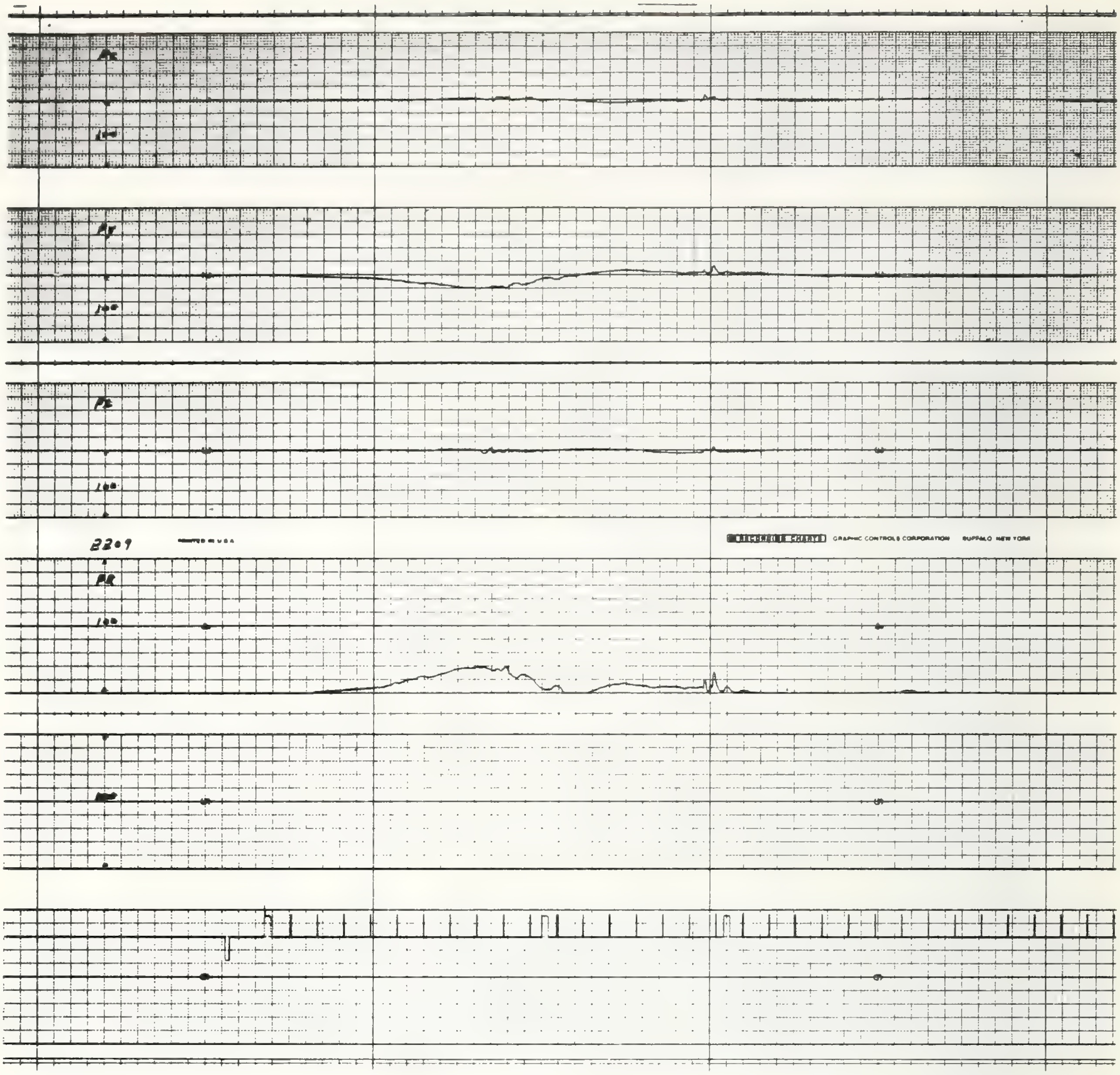
Time = 10 ms/division



Time = 10 ms/division



Time = 10 ms/division



Time = 10 ms/division

APPENDIX B

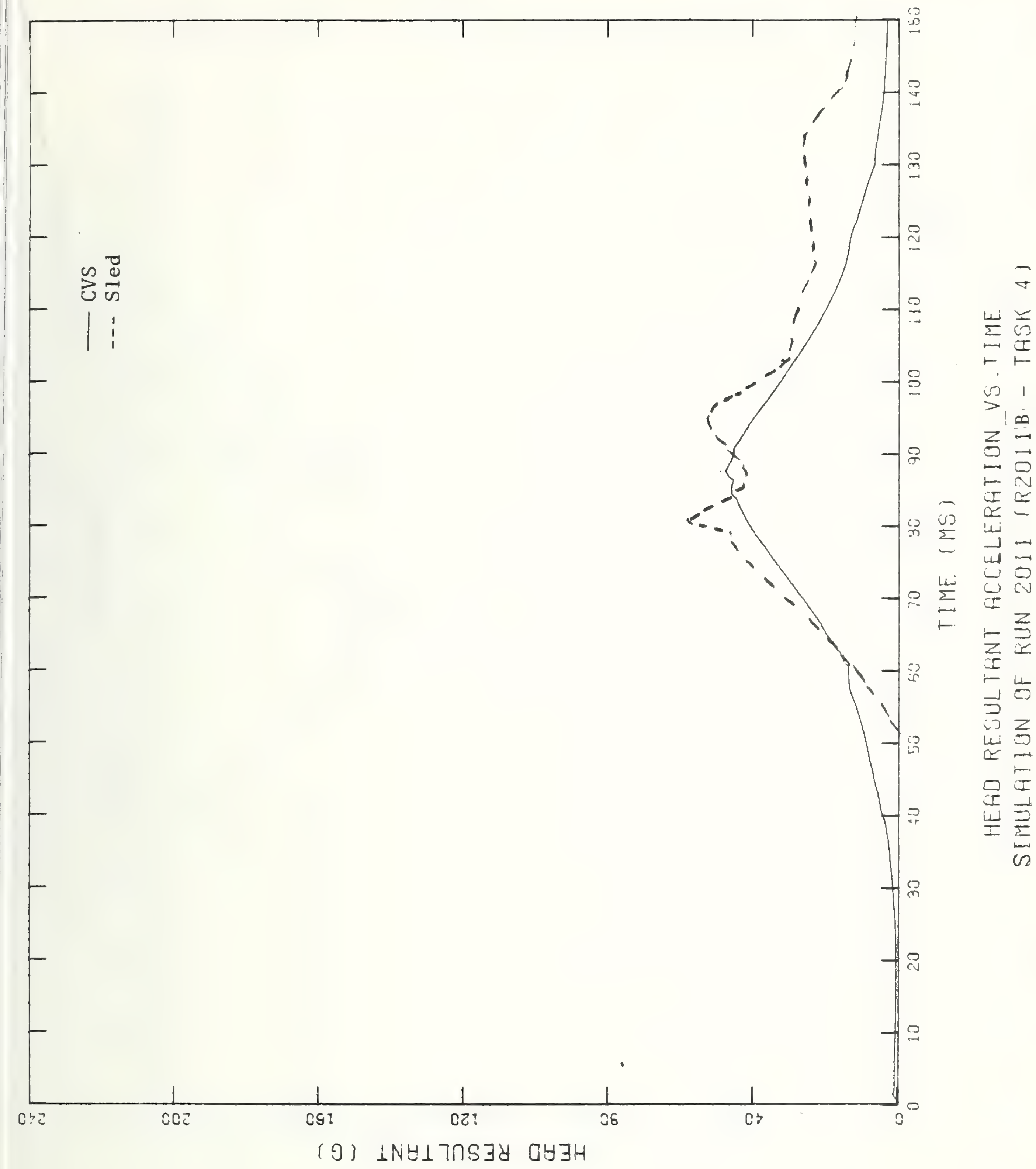
COMPUTER SIMULATION DATA TRACES

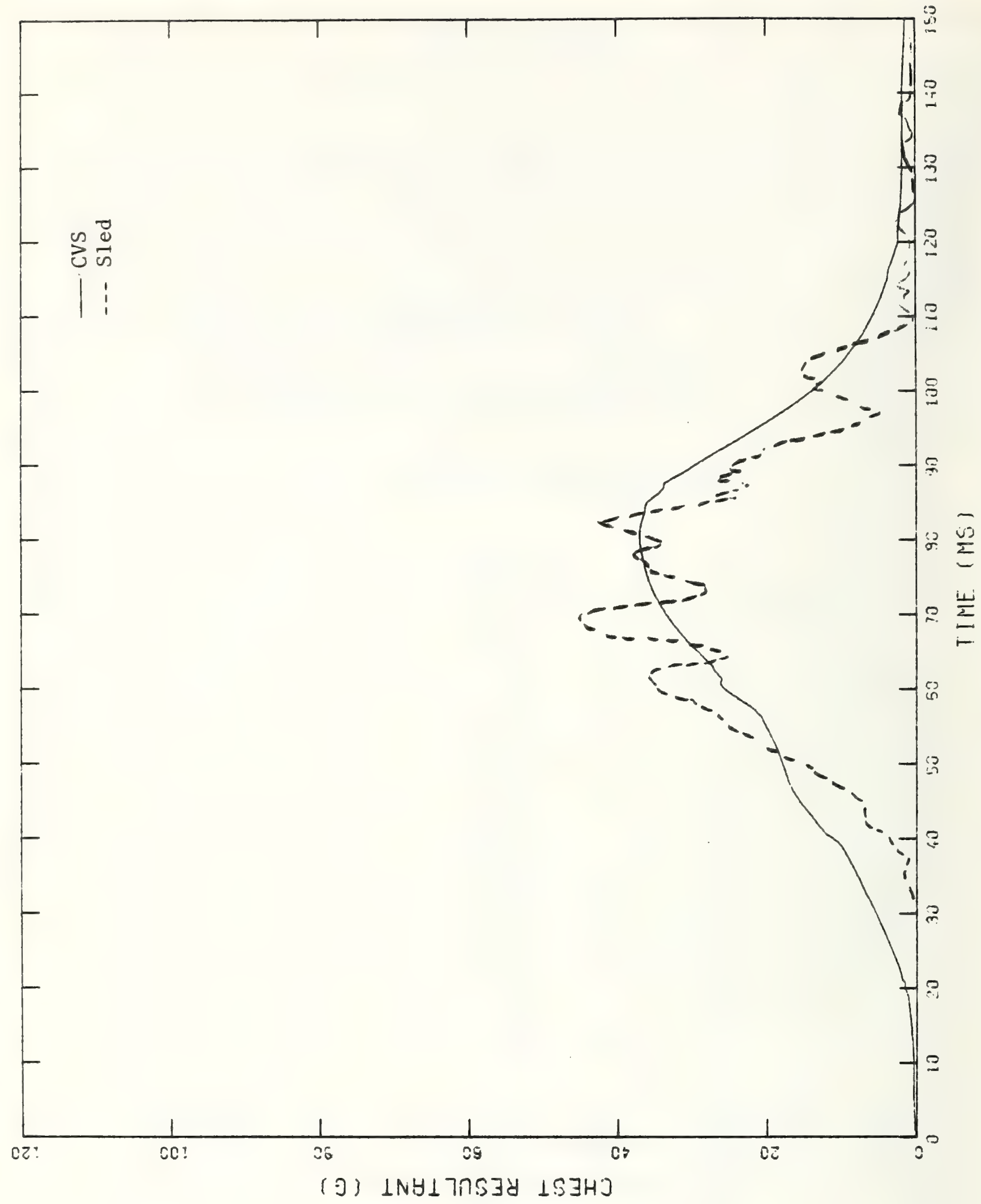
INDEX TO APPENDIX B

Appendix B contains data traces from the nineteen final computer simulations overlayed with the correlating sled run data where applicable. The data traces include the following:

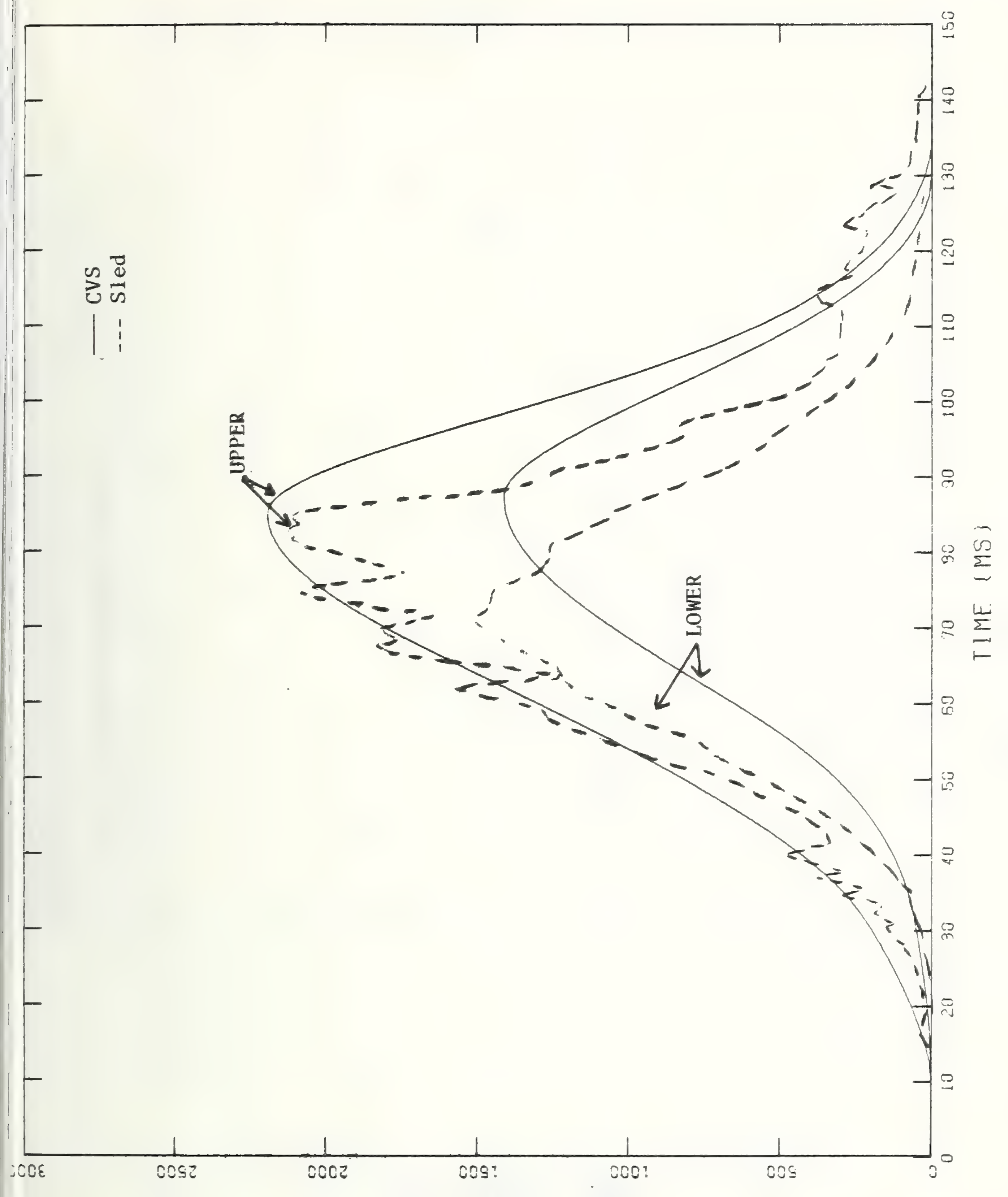
Head Resultant Acceleration vs. Time
Chest Resultant Acceleration vs. Time
Belt Loads vs. Time
Head Z Displacement vs. Head X Displacement
Right and Left Femur Loads vs. Time

COMPUTER SIMULATION DATA TRACES

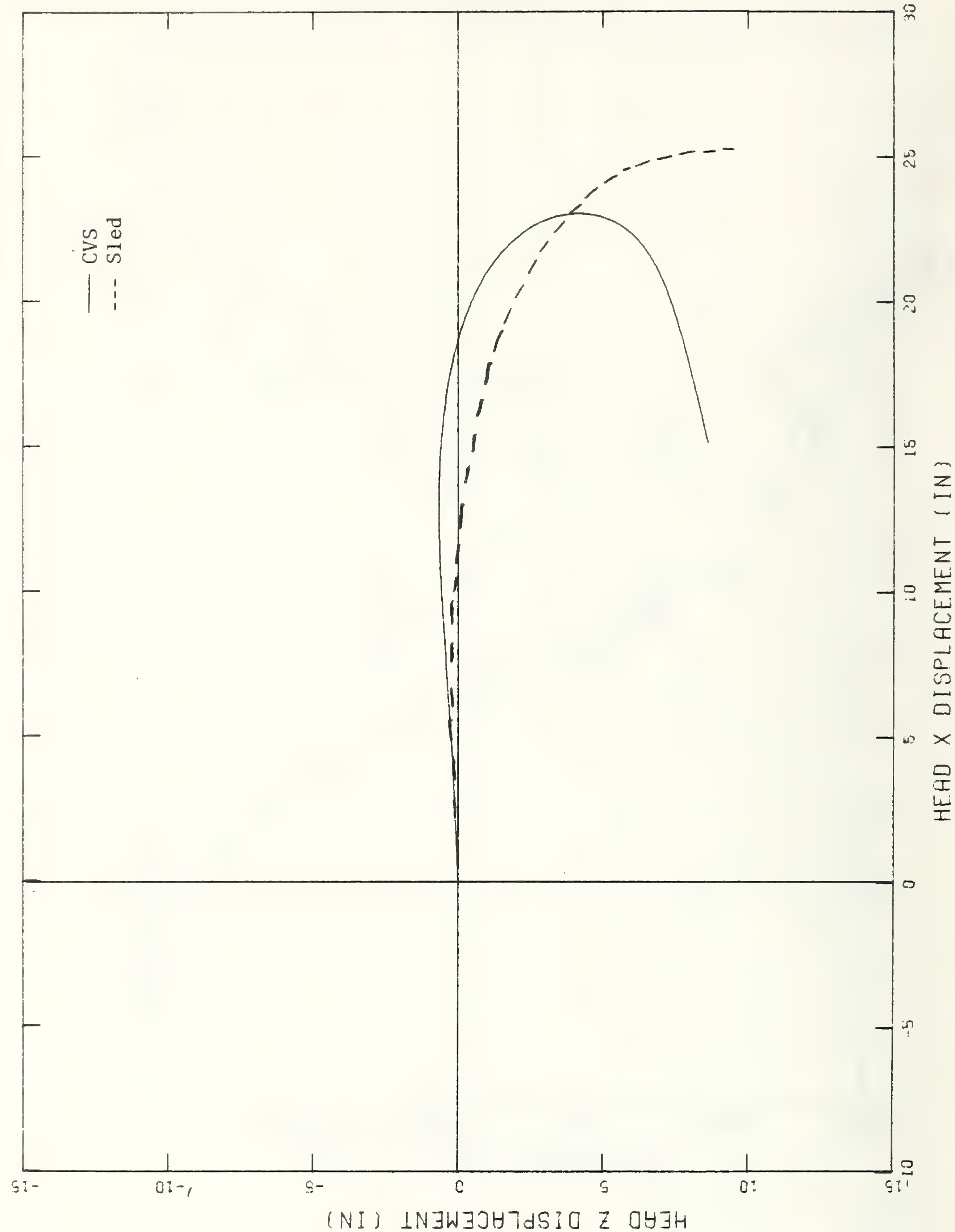

CVS
Sled
HEAD RESULTANT (G)
0
40
80
120
160
200
240
TIME (MS)
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2011 (R2011B - TASK 4)



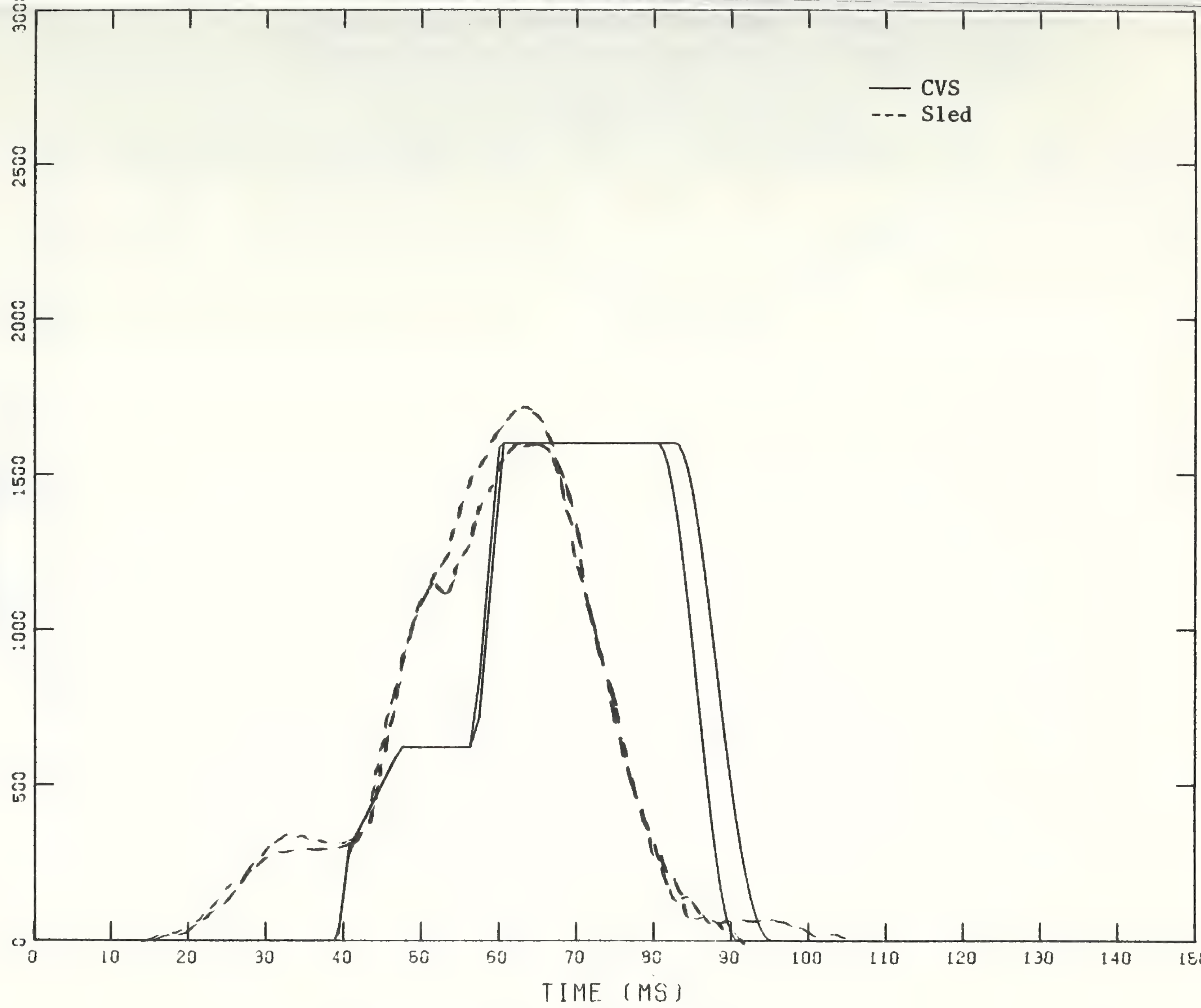
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2011 (R2011B - TASK 4)



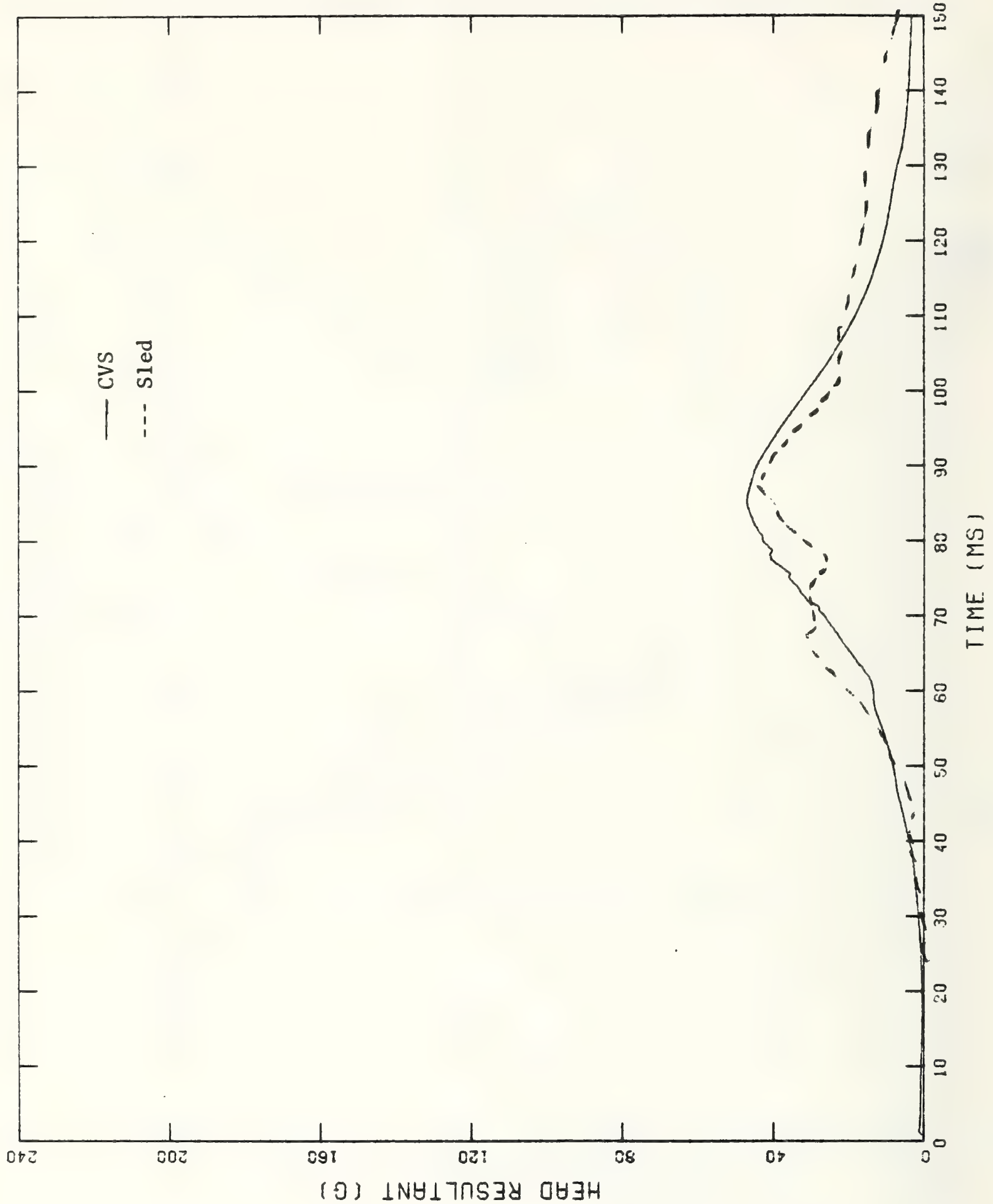
BELT LOADS VS. TIME
SIMULATION OF RUN 2011 (R2011B - TASK 4)



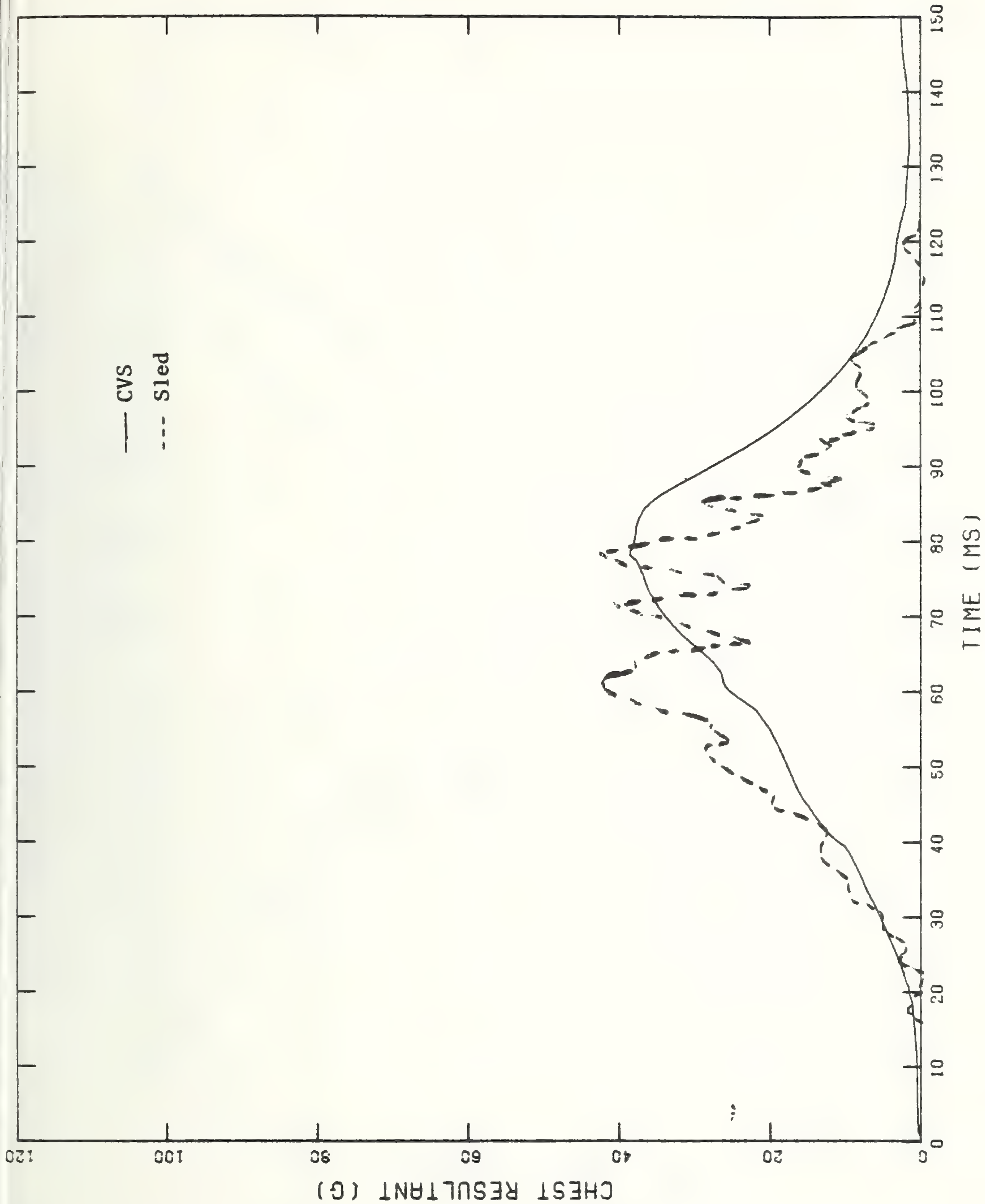
HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2011 (R2011B - TASK 4)



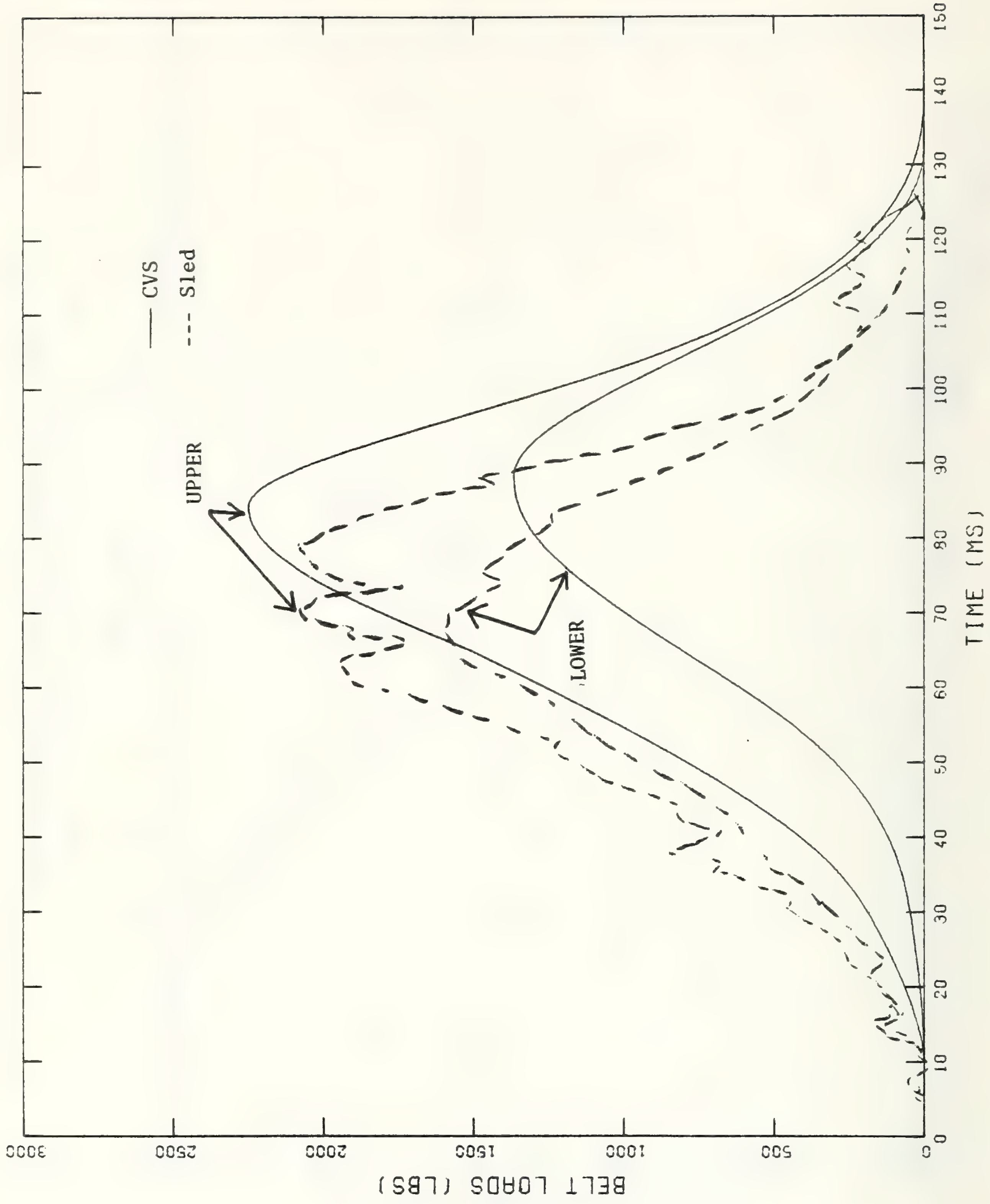
RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2011 (R2011B - TASK 4)



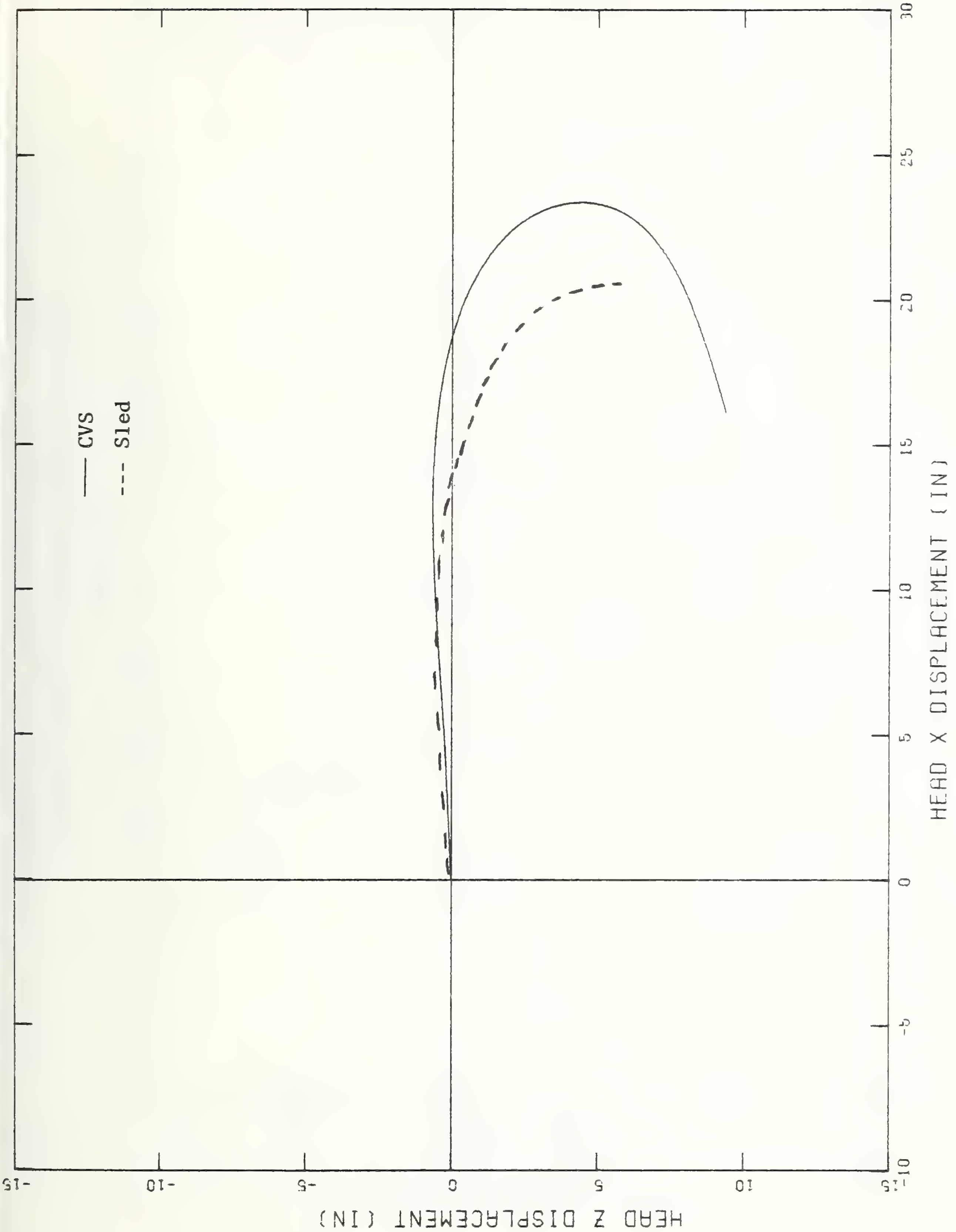
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2010 (R2010B - TASK 4)



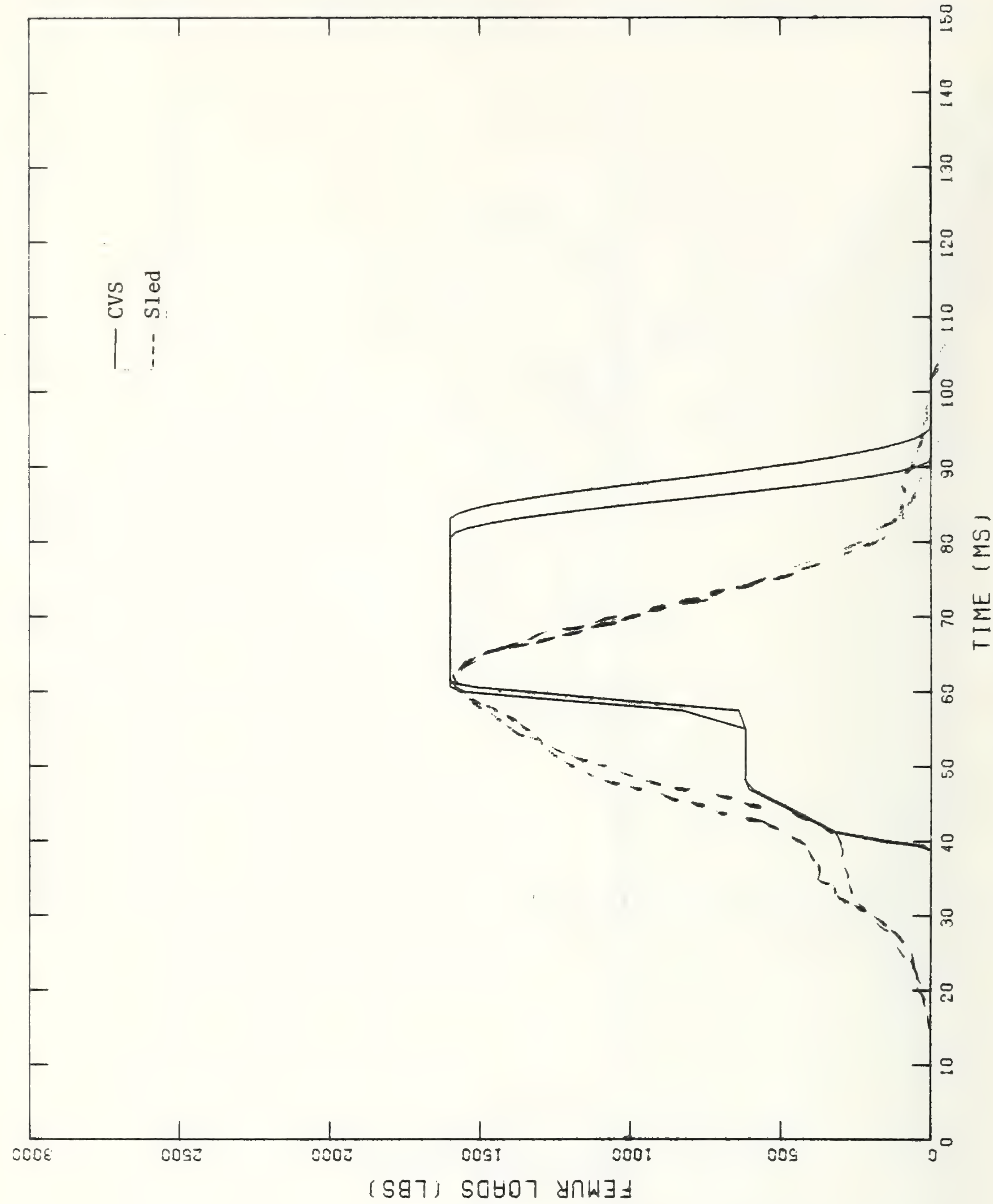
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2010 (R2010B - TASK 4)



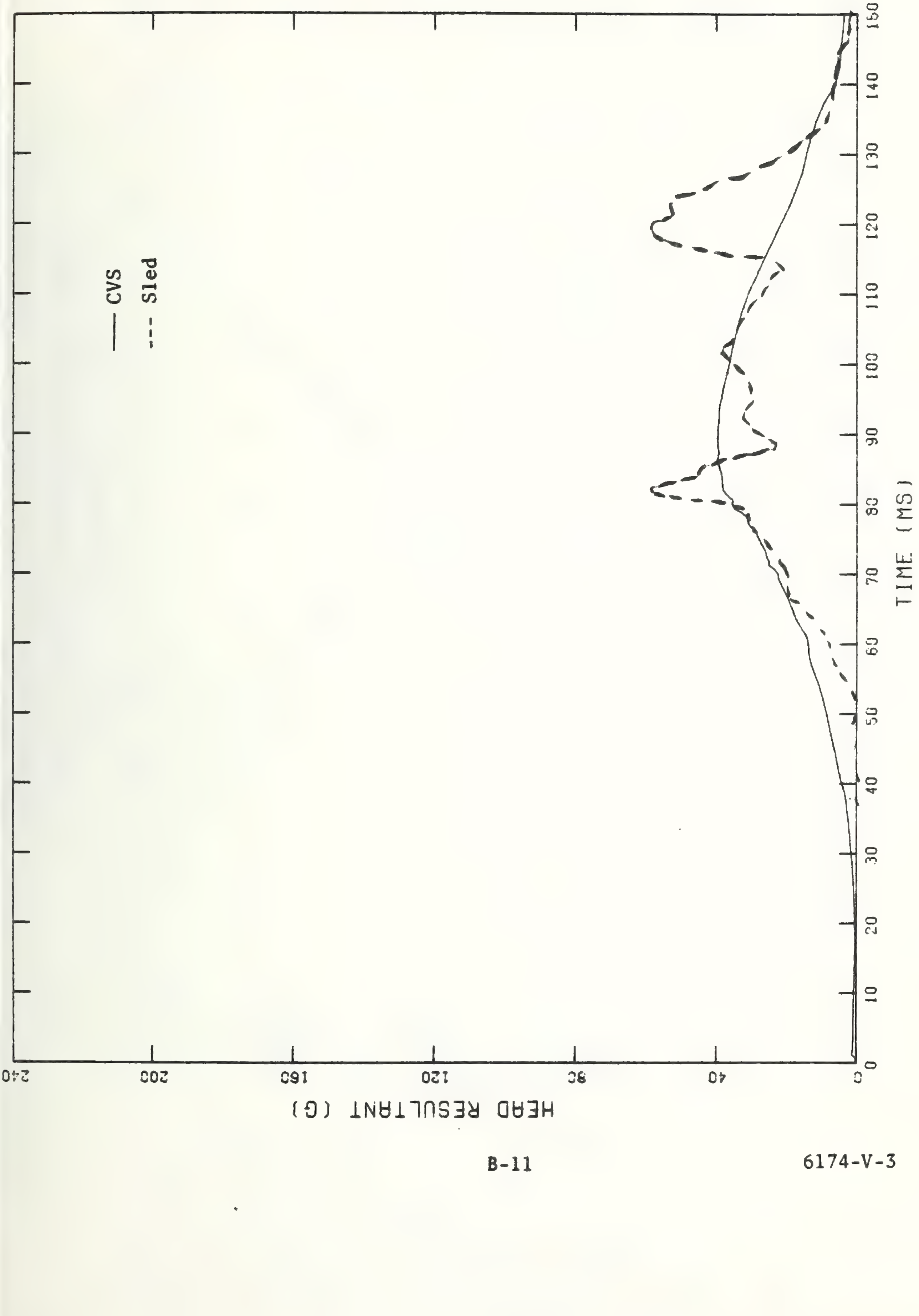
BELT LOADS VS. TIME
SIMULATION OF RUN 2010 (R2010B - TASK 4)



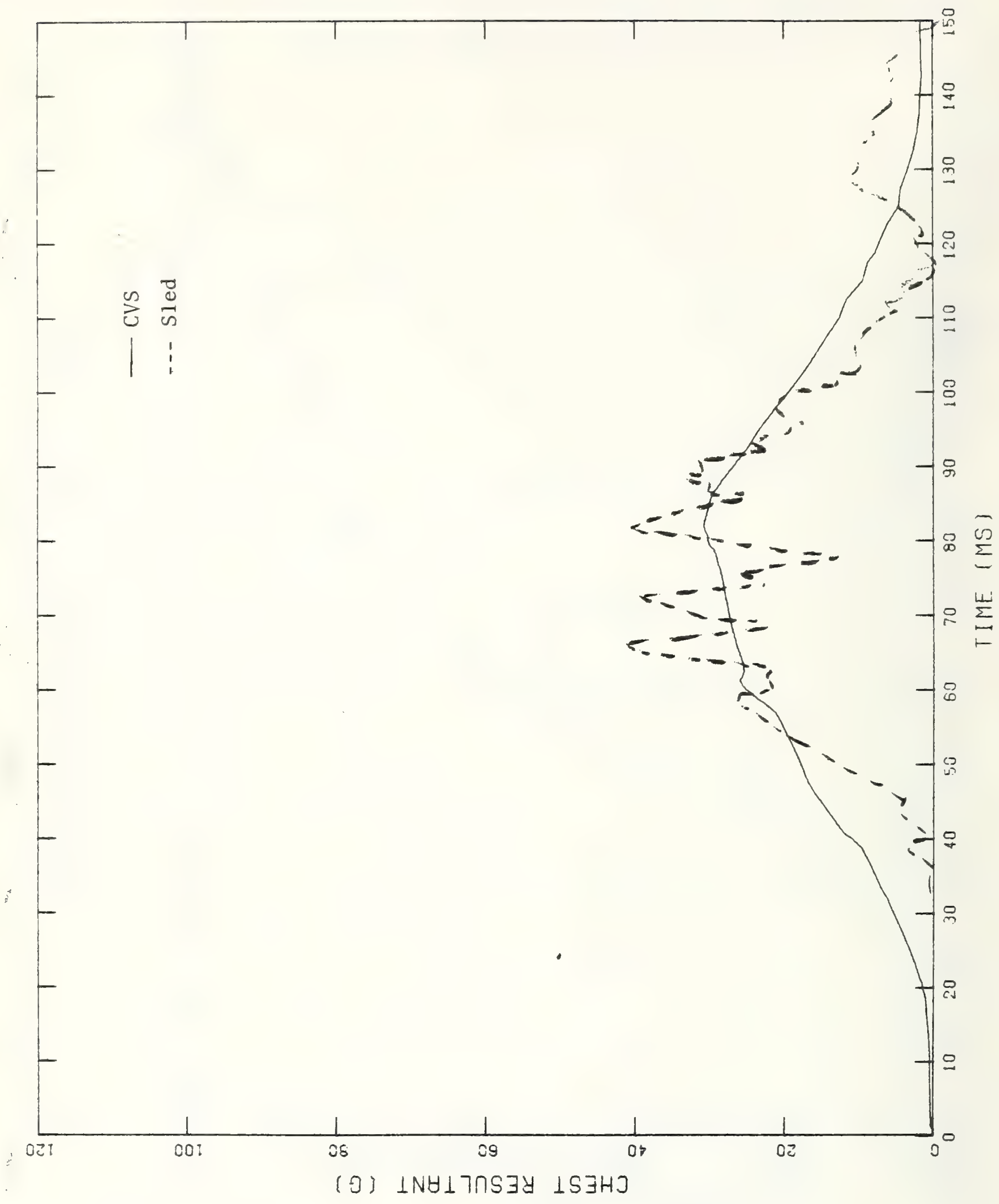
HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2010 (R2010B - TASK 4)



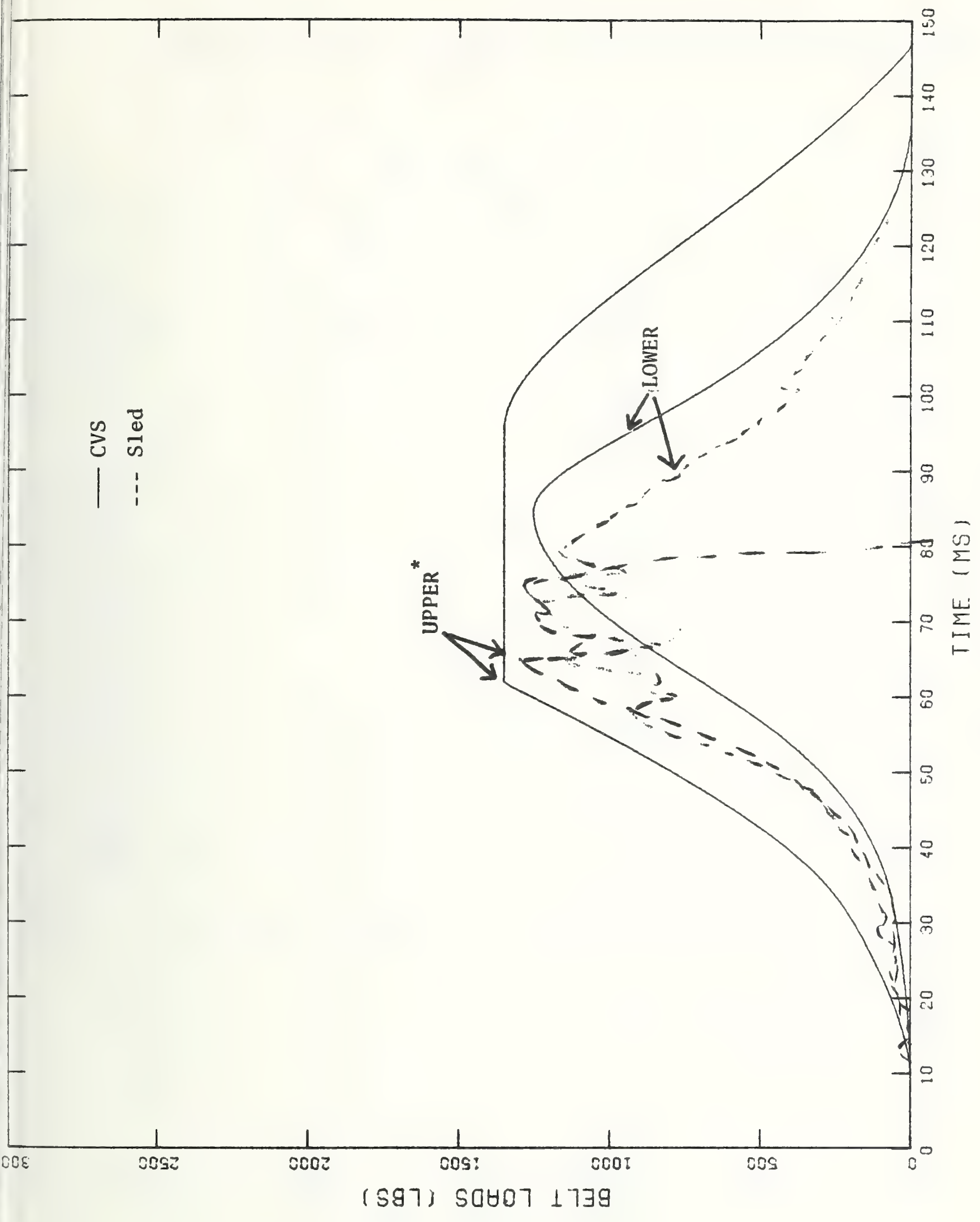
RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2010 (R2010B - TASK 4)



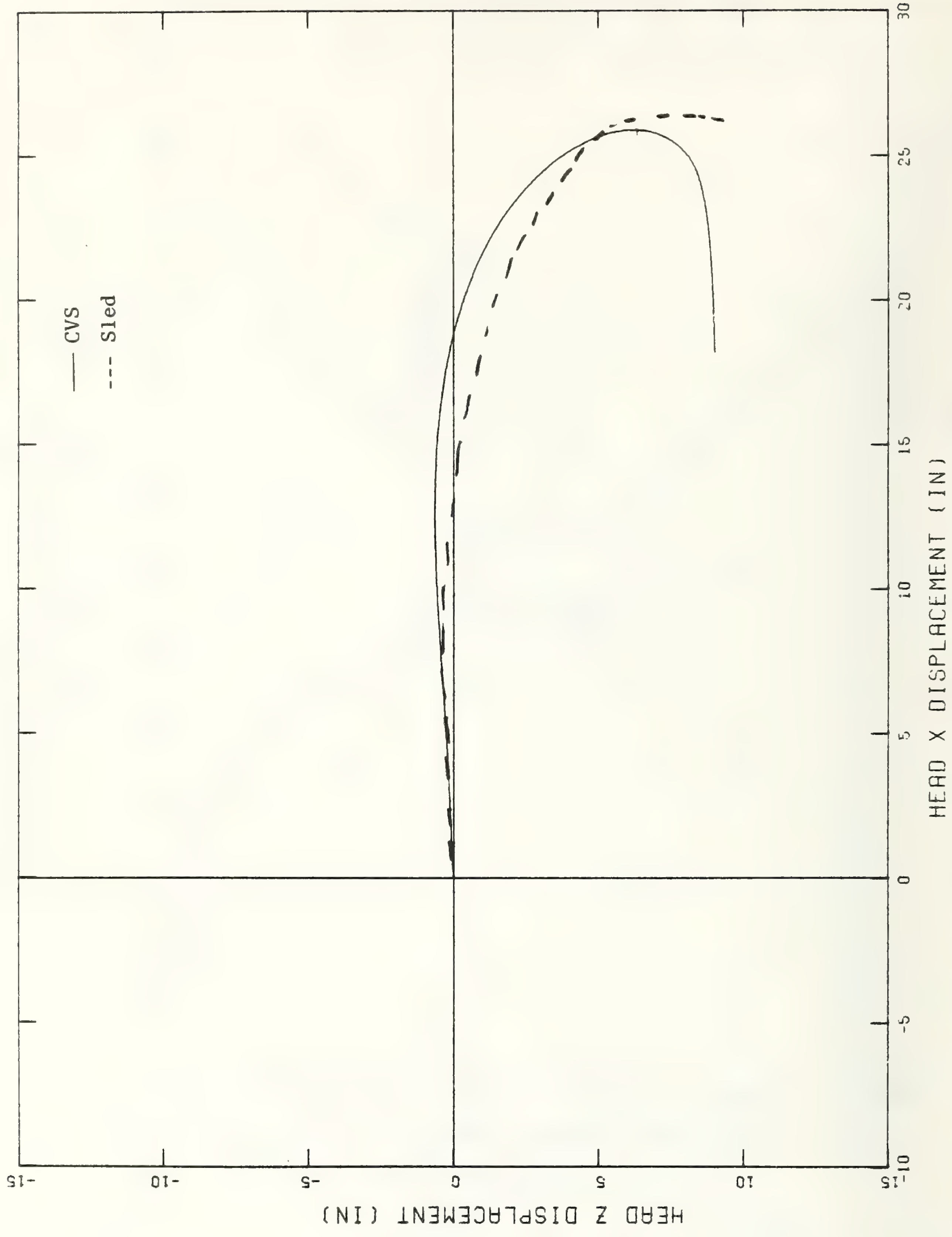
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2019 (R2019B - TASK 4)



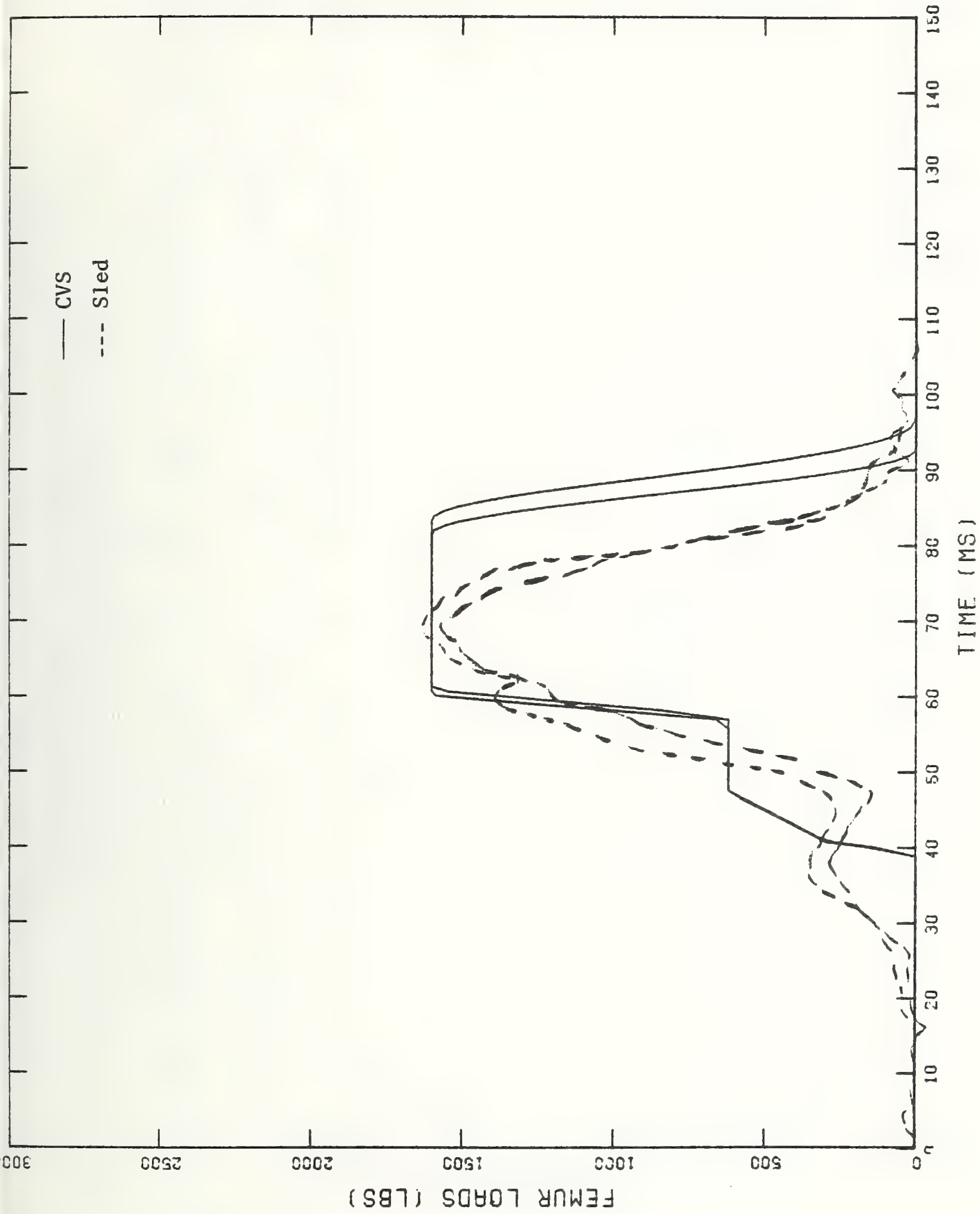
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2019 (R2019B - TASK 4)



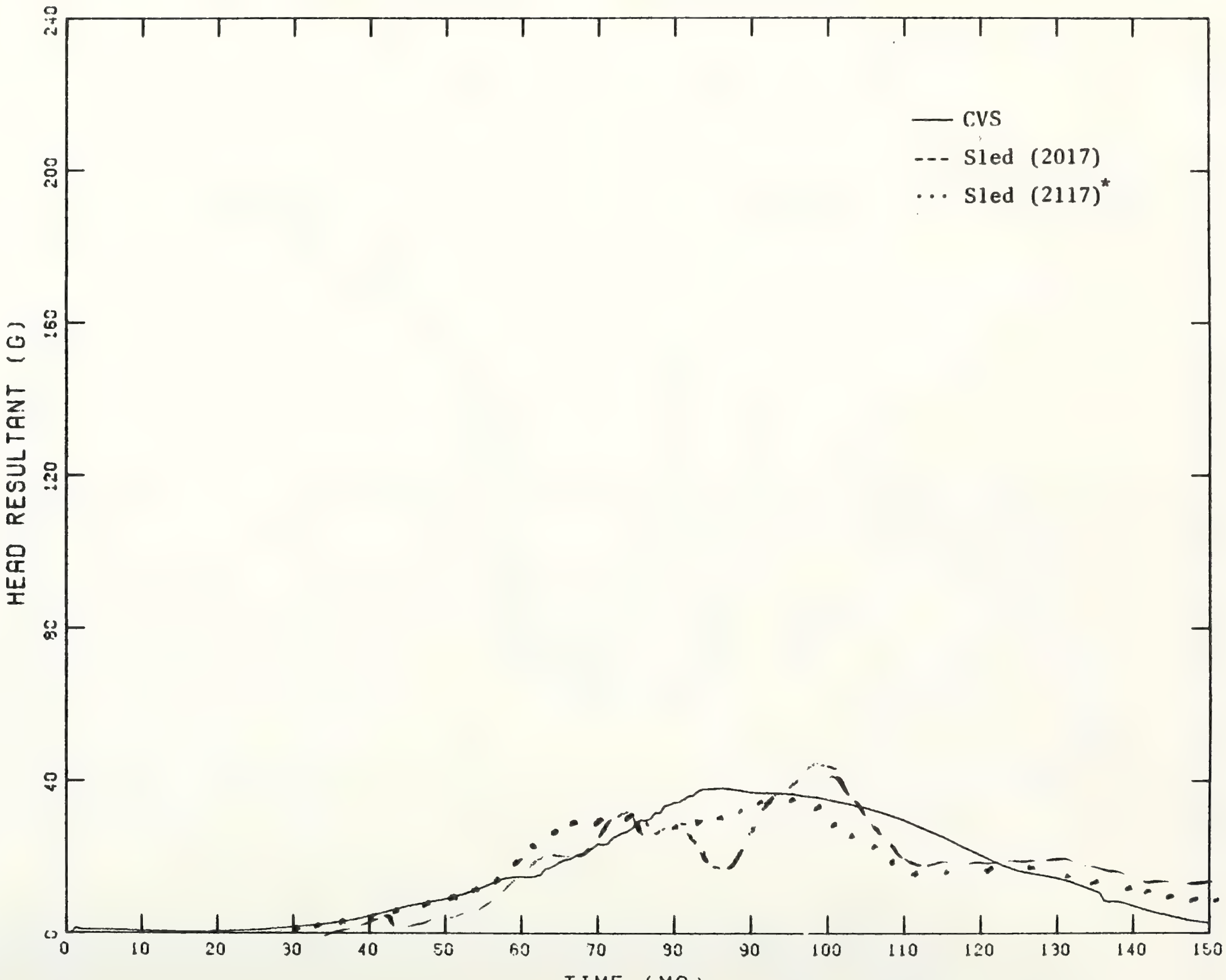
BELT LOADS VS. TIME
SIMULATION OF RUN 2019 (R2019B - TASK 4)
*LOAD CELL OPENED



HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2019 (R2019B - TASK 4)

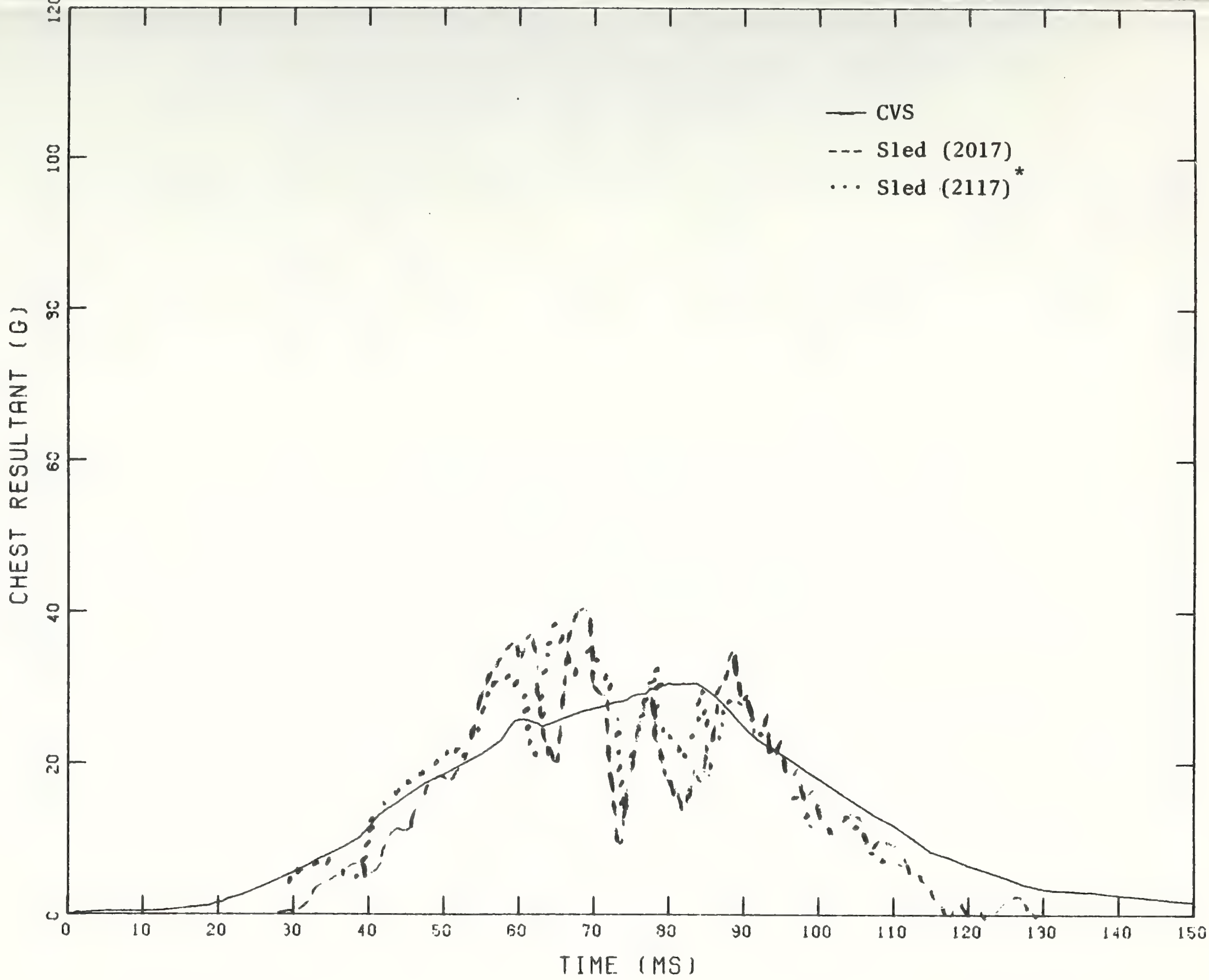


RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2019 (R2019B - TASK 4)



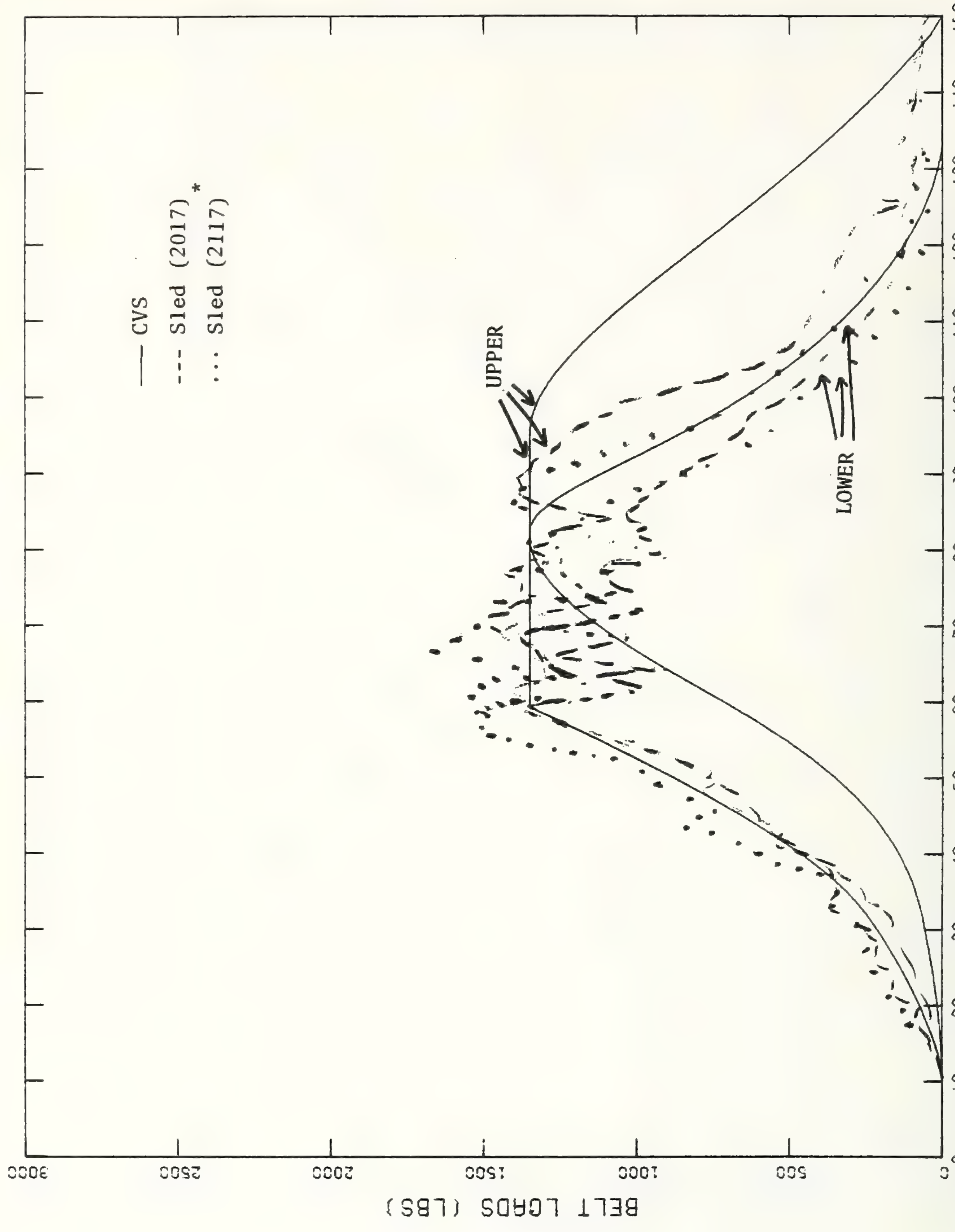
HEAD RESULTANT ACCELERATION VS.TIME
SIMULATION OF RUN 2017 (R2017B - TASK 4)

*Run 2117 - Repeat of Run 2017



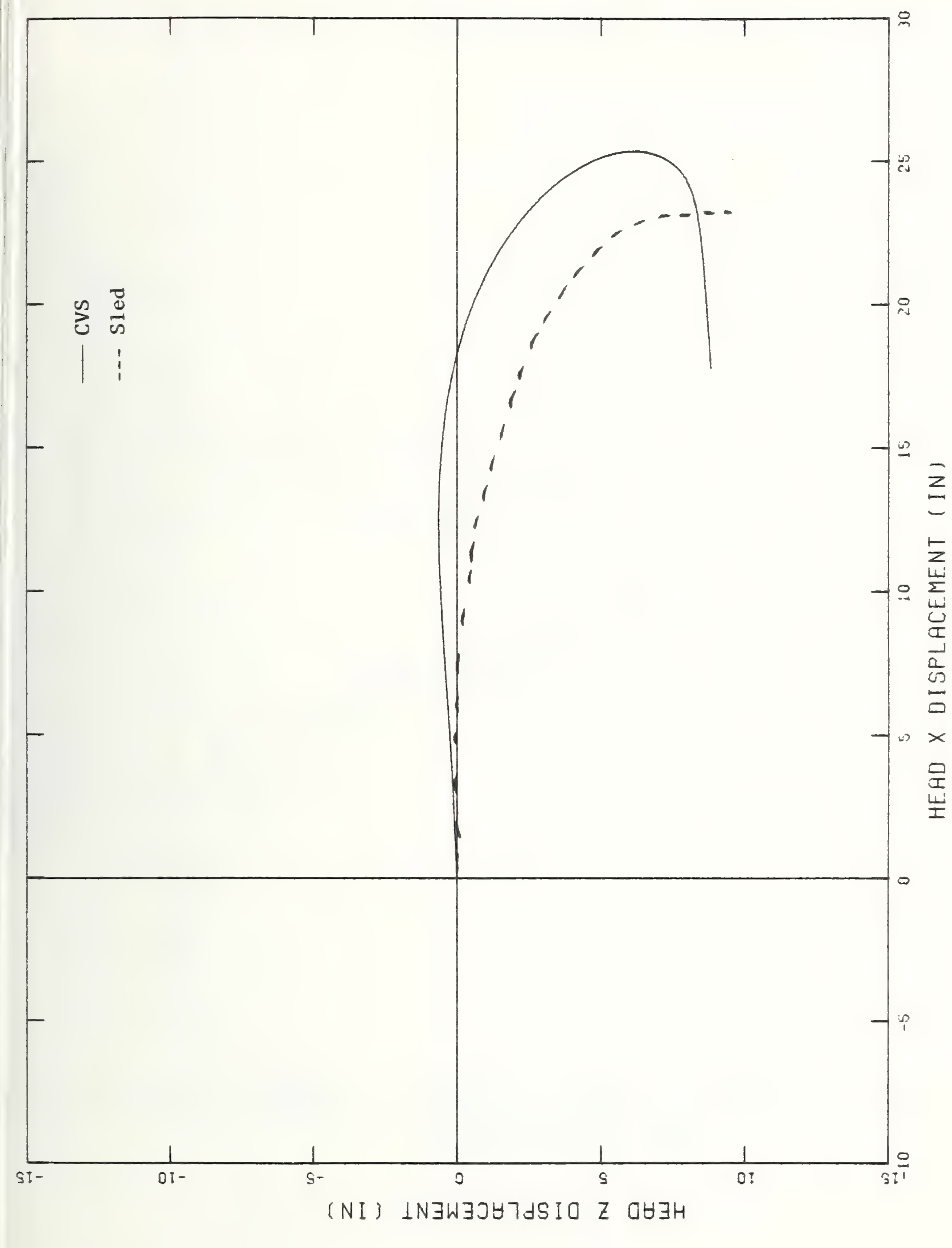
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2017 (R2017B - TASK 4)

*Repeat of Run 2017

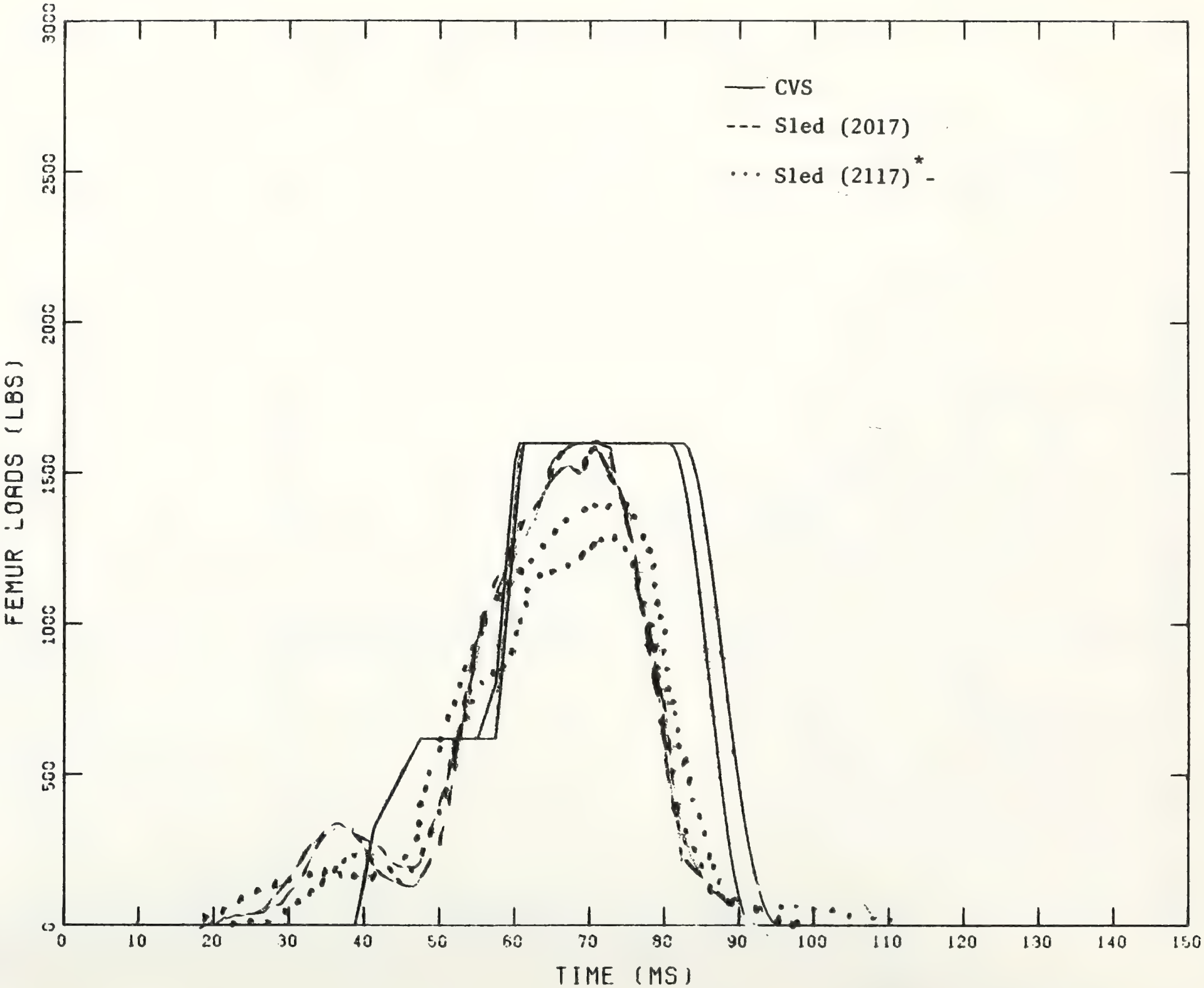


BELT LOADS VS. TIME
SIMULATION OF RUN 2017 (R2017B - TASK 4)

*Repeat of Run 2017

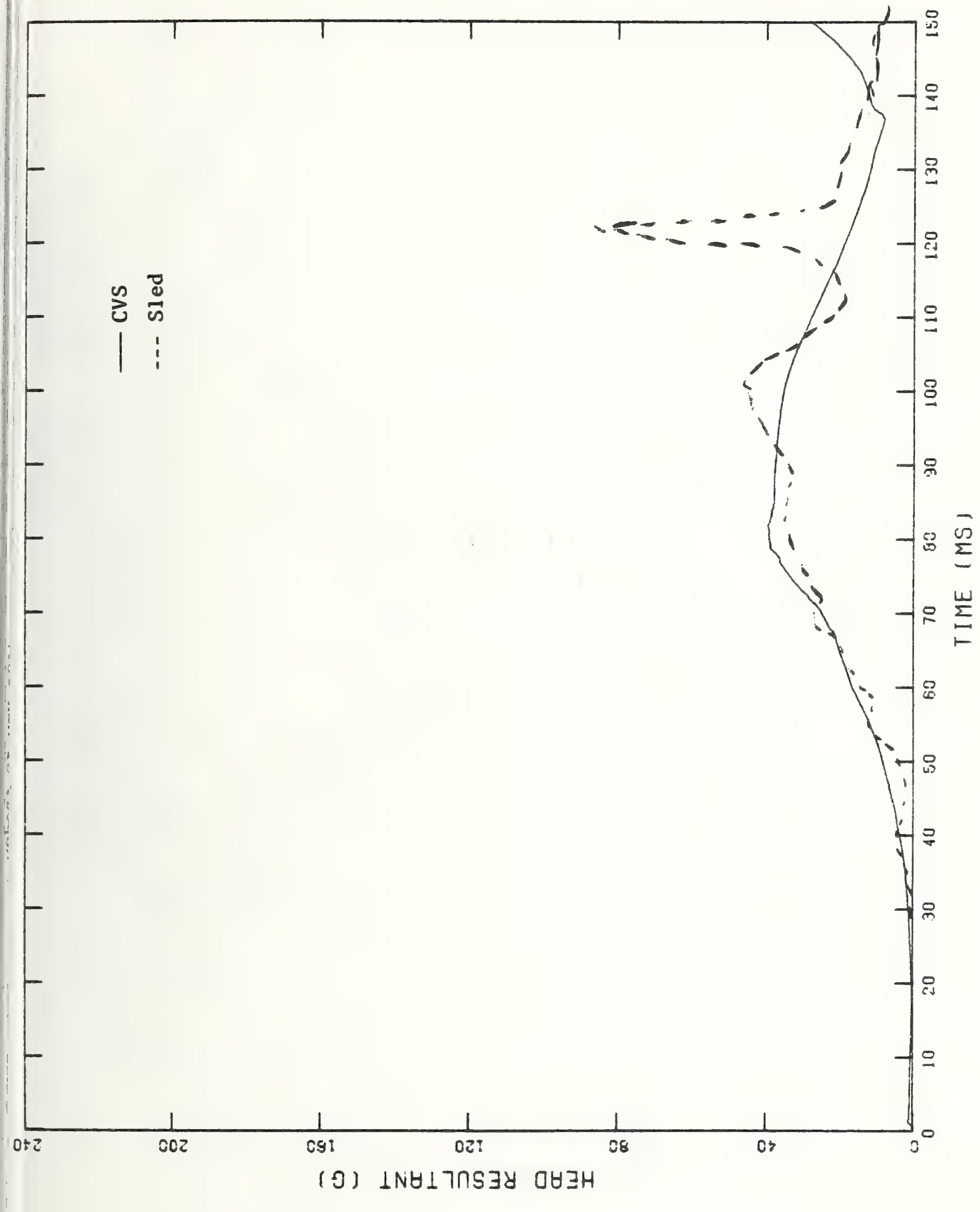


HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2017 (R2017B - TASK 4)

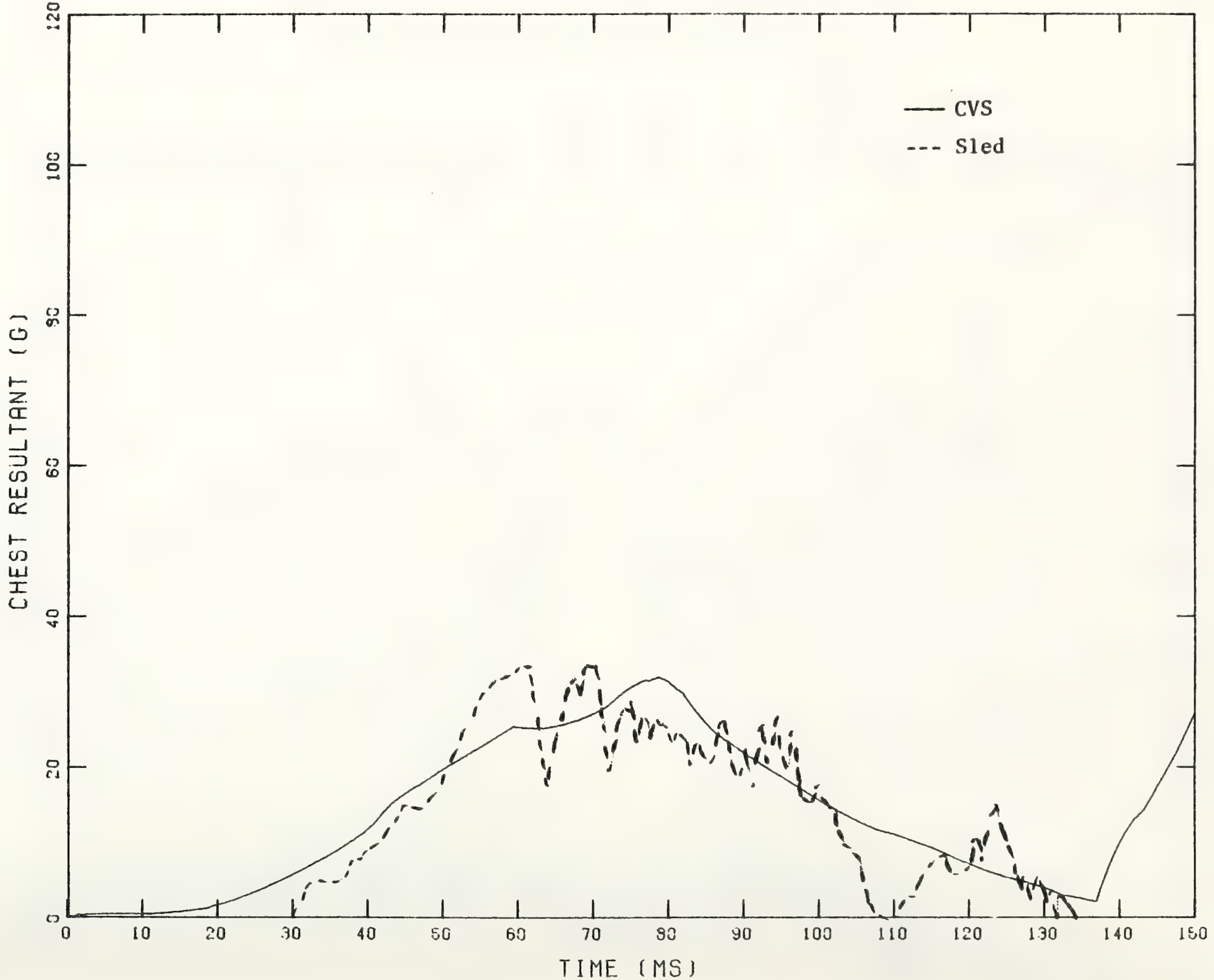


RICHT AND LEFT FEMUR LOADS VS. TIME
SIMULATIONS OF RUNS 2017

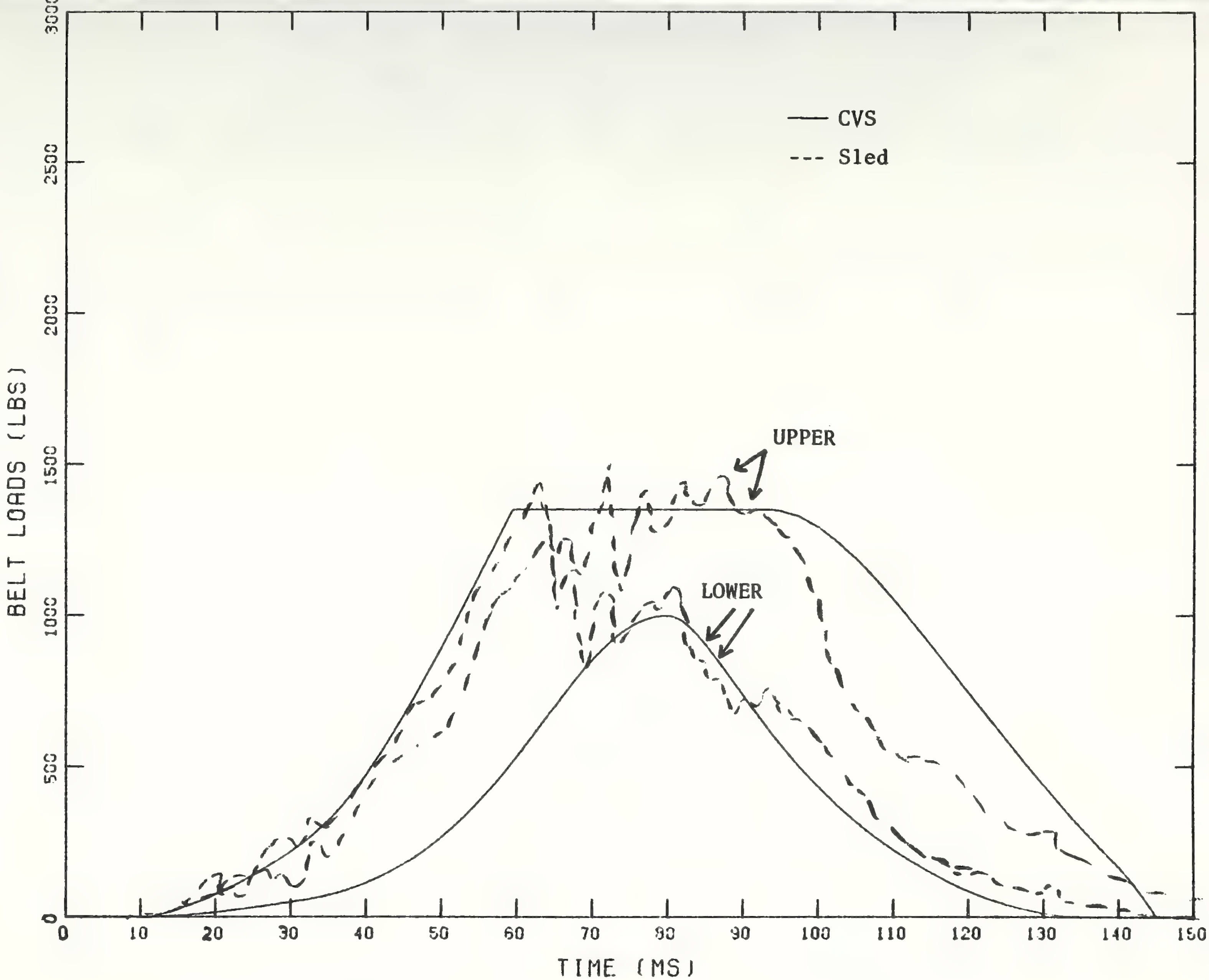
*Repeat of Run 2017



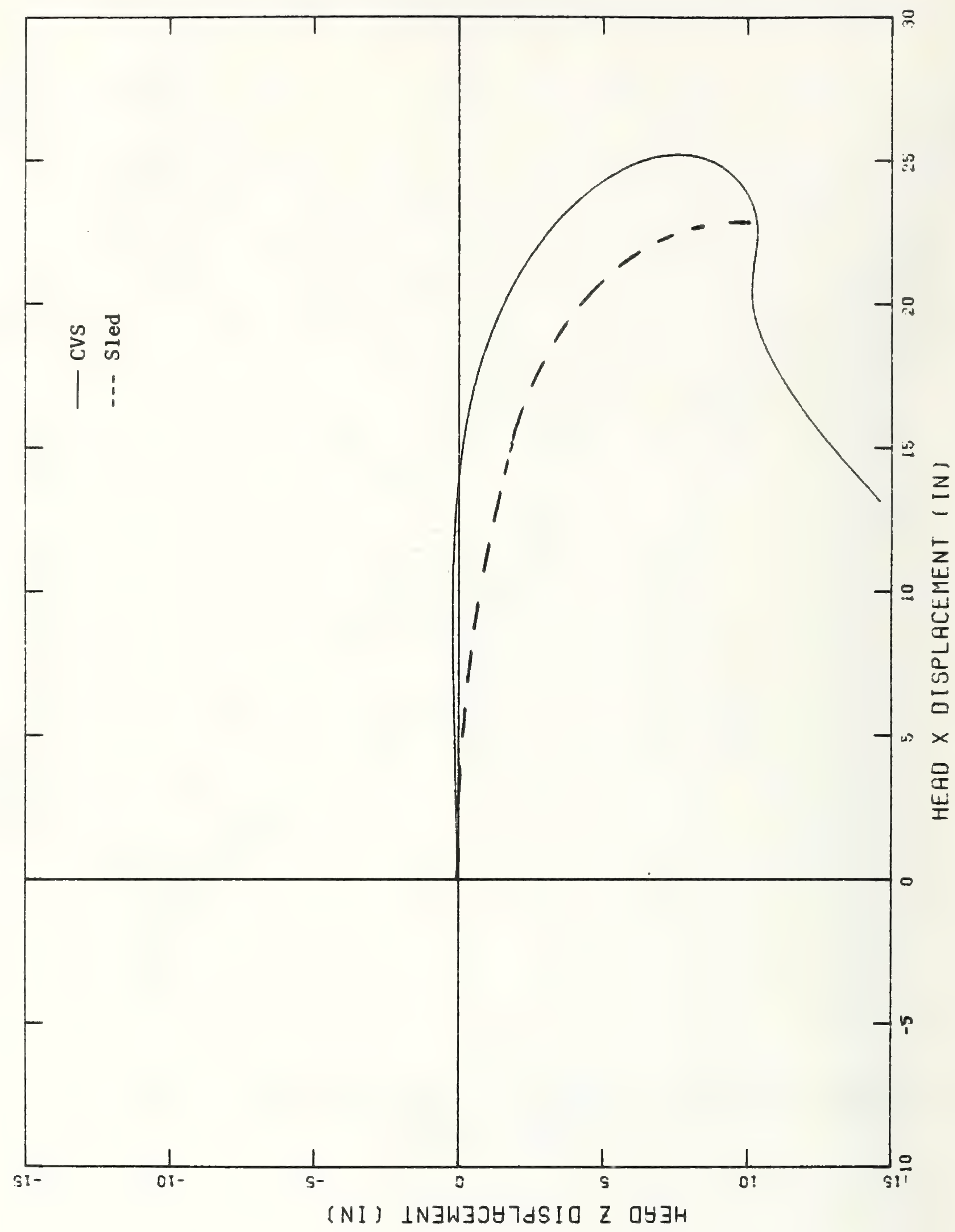
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2018 (R2018B - TASK 4)



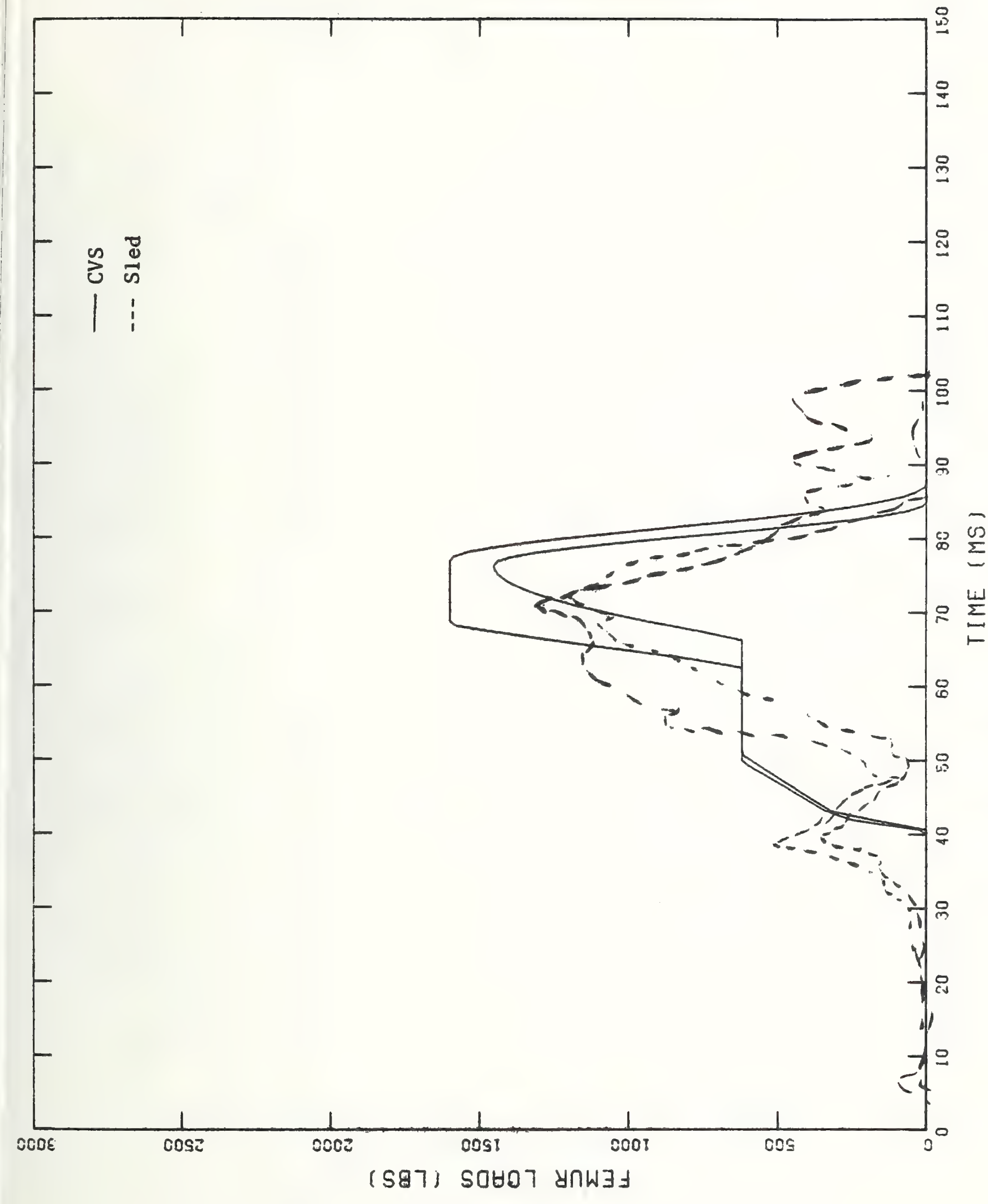
CHEST RESULTANT ACCELERATION VS.TIME
SIMULATION OF RUN 2018 (R2018B - TASK 4)



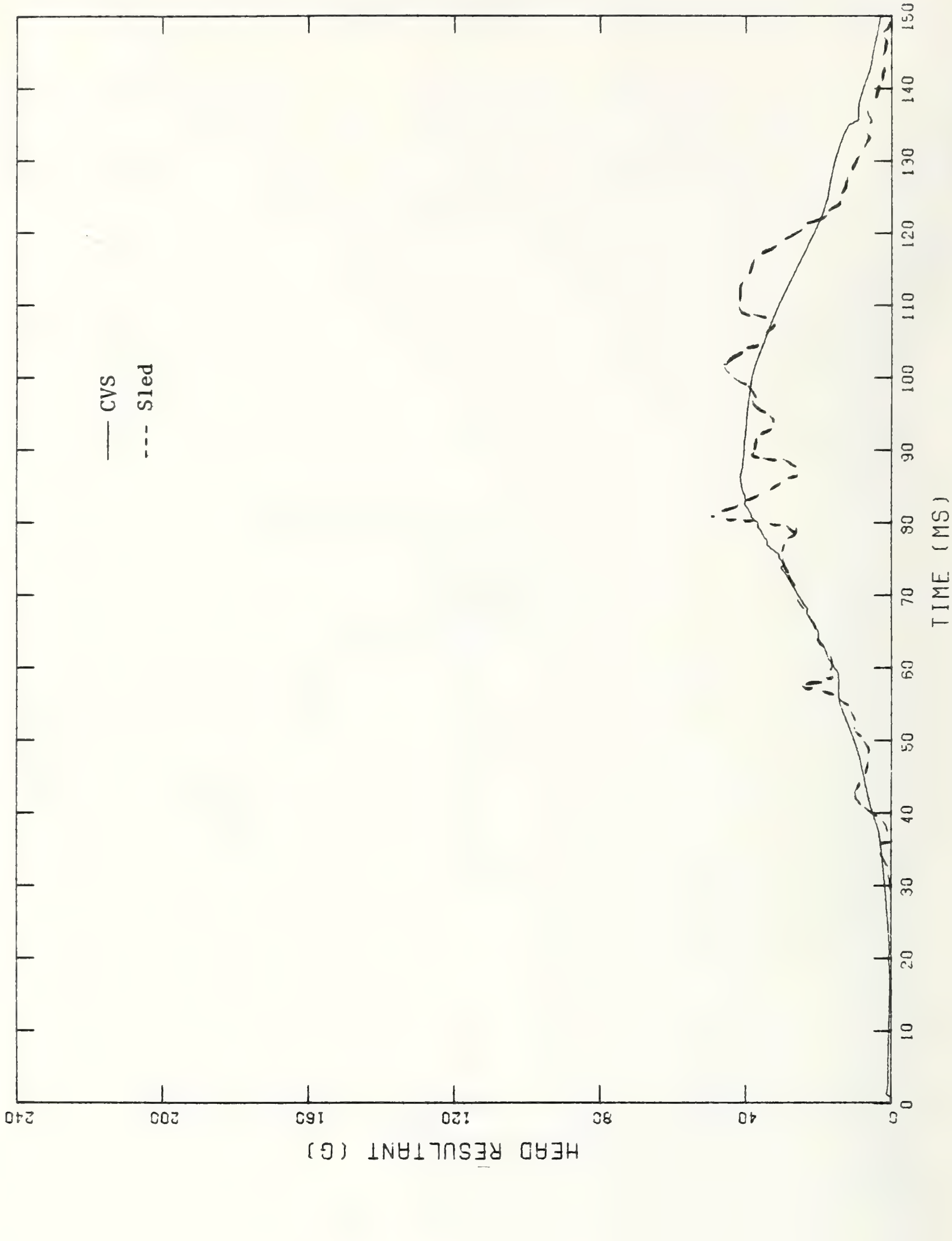
BELT LOADS VS. TIME
SIMULATION OF RUN 2018 (R2018B - TASK 4)



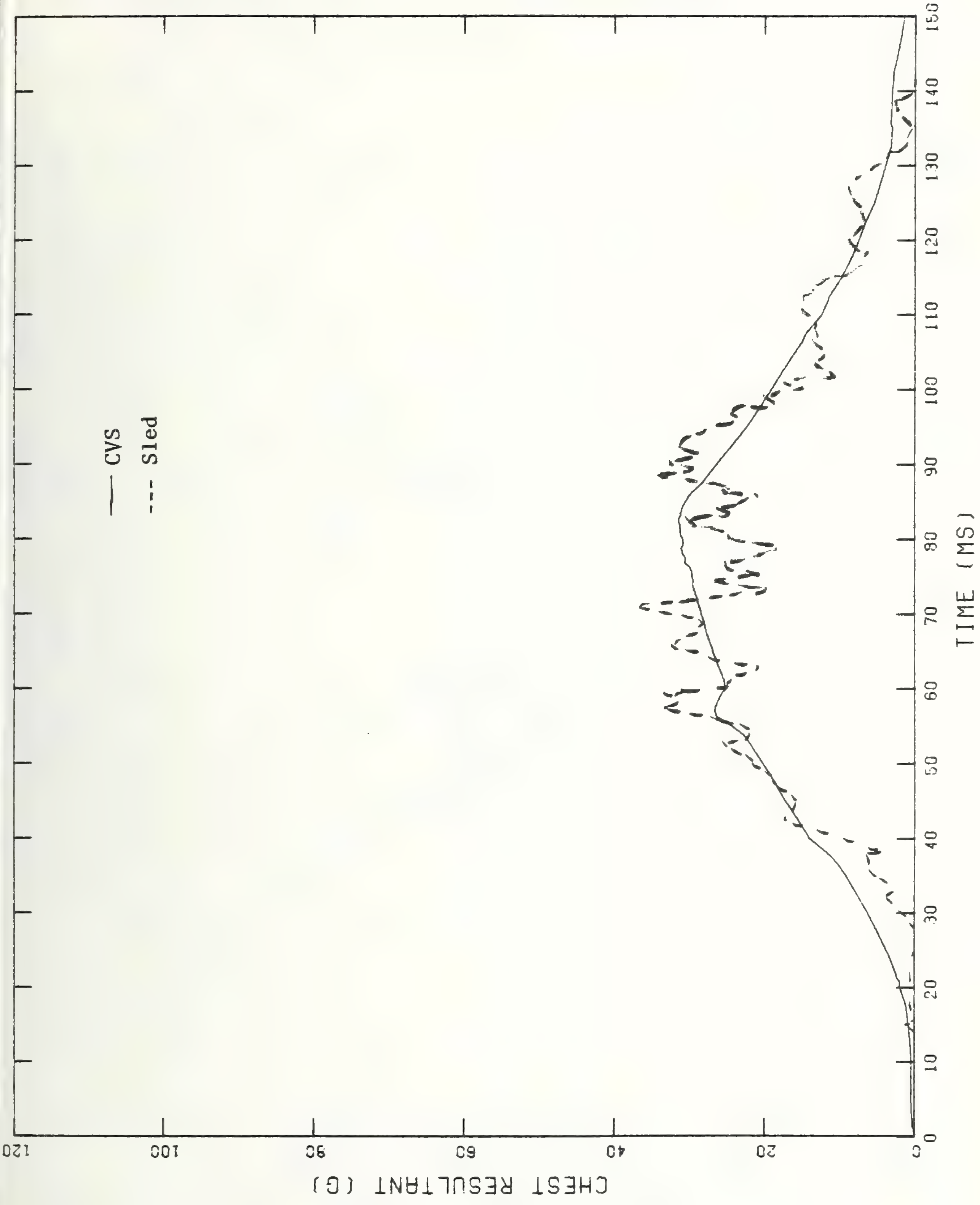
HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2018 (R20186 - TASK 4)



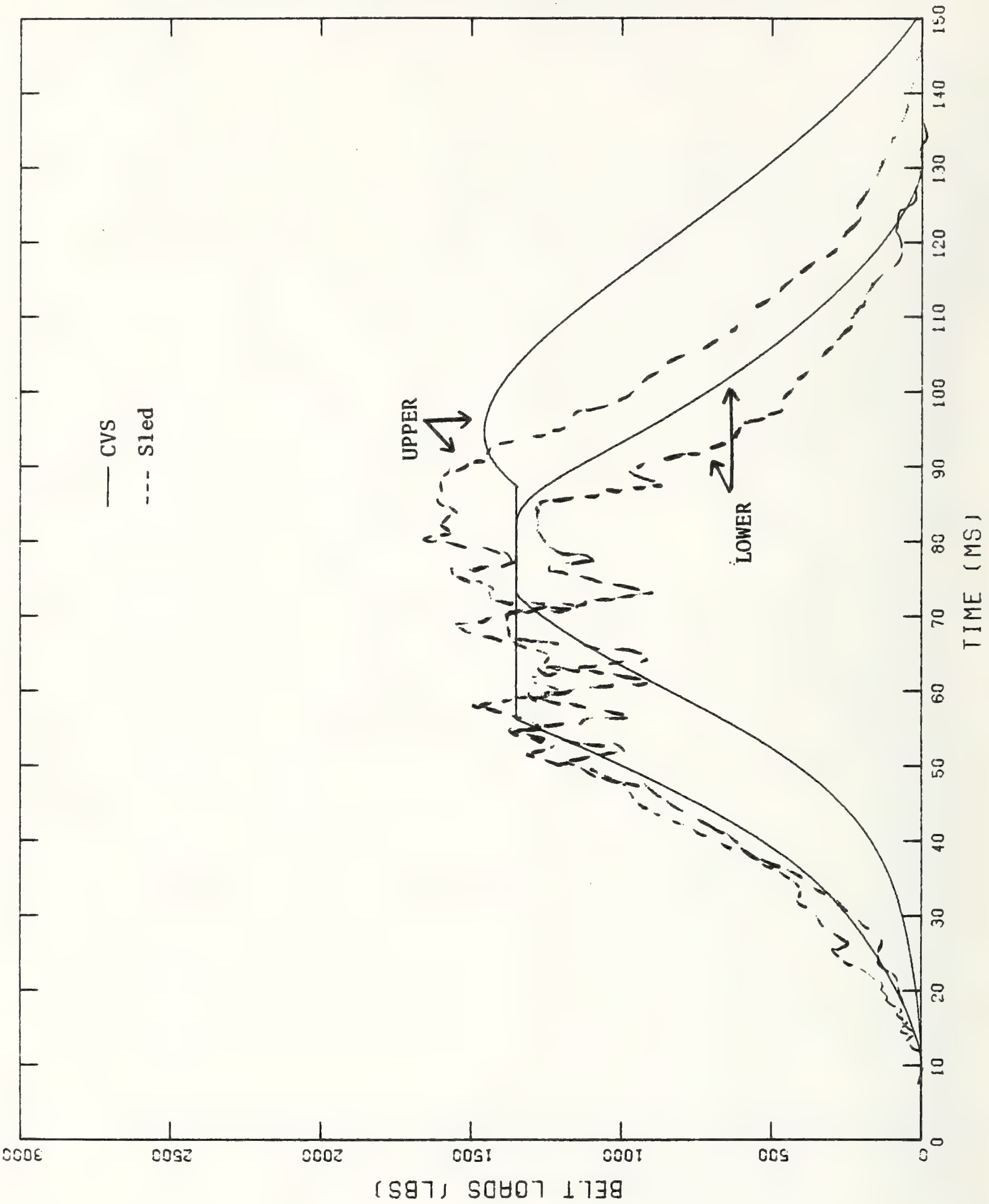
RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2018 (R2018B - TASK 4)



HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2027 (R2027C - TASK 4)

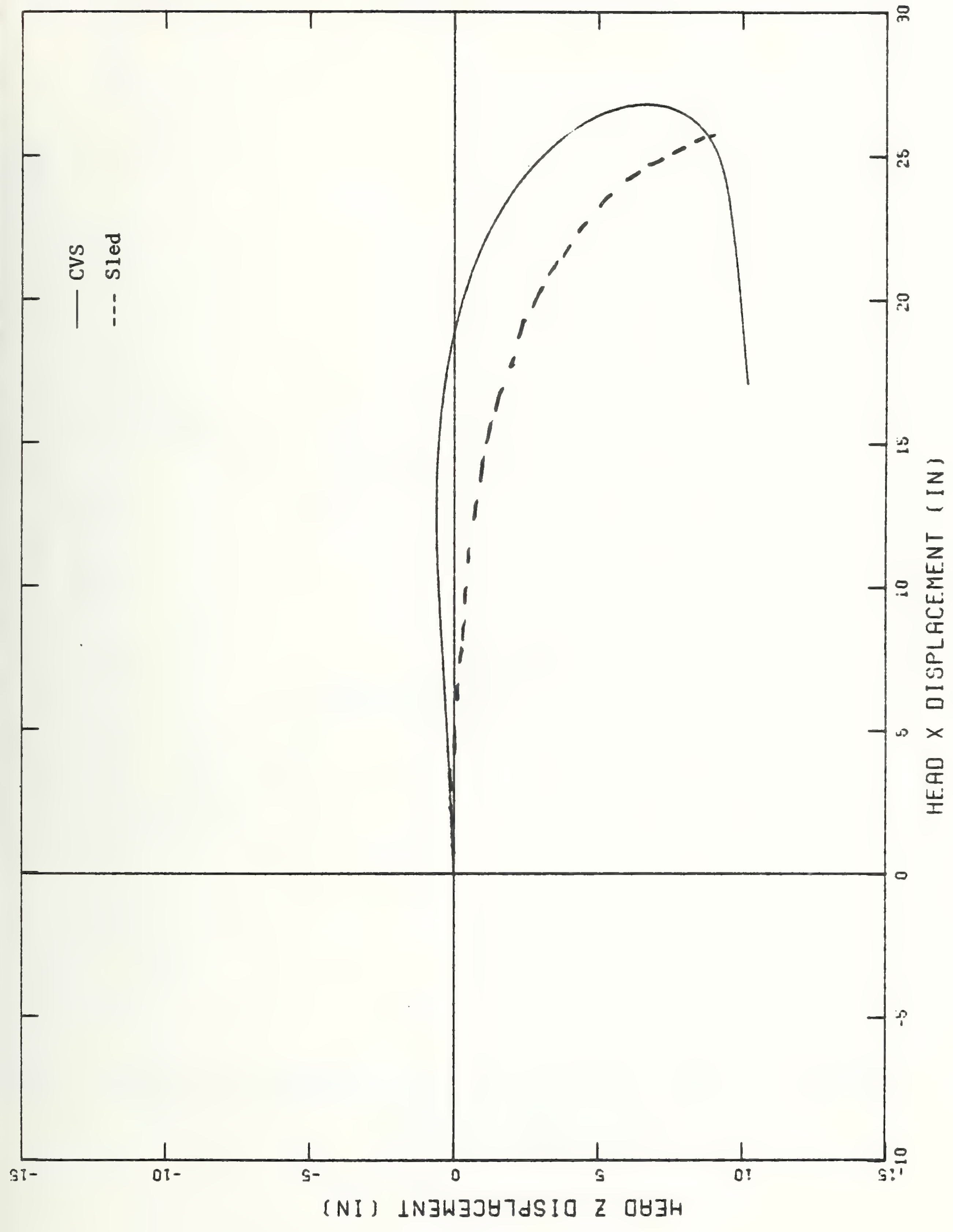


CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2027 (R2027C - TASK 4)

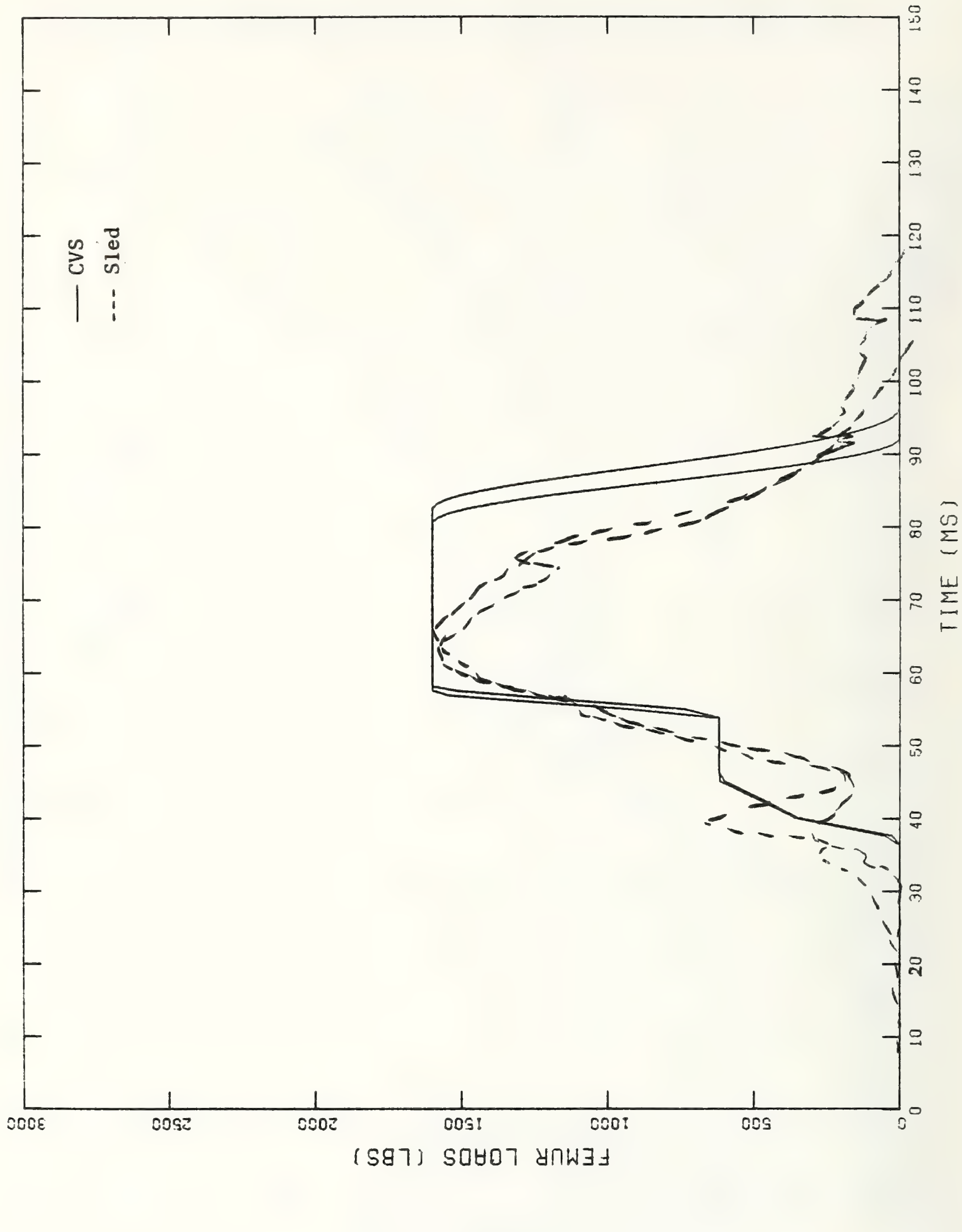


BELT LOADS VS. TIME

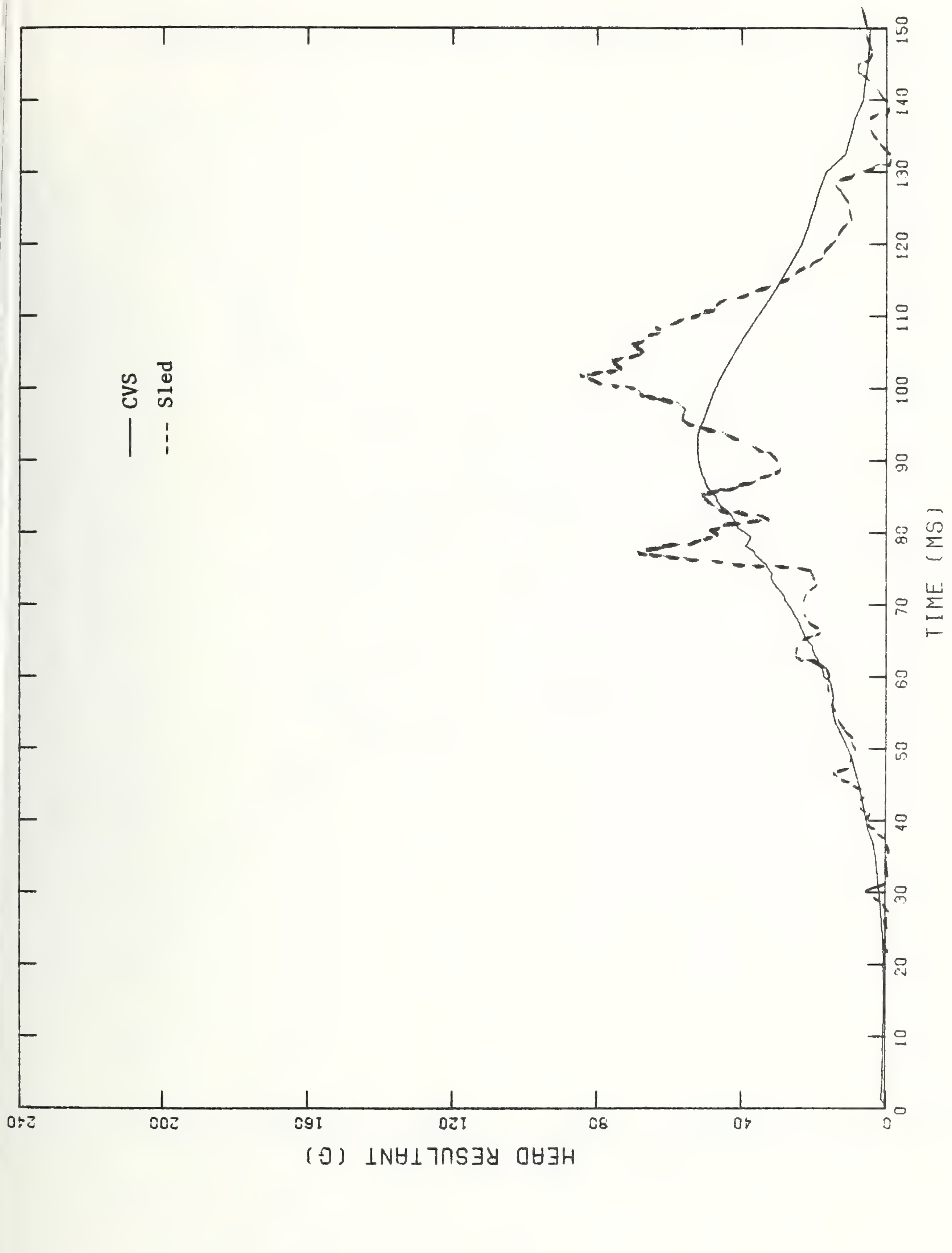
SIMULATION OF RUN 2027 (R2027C - TASK 4)



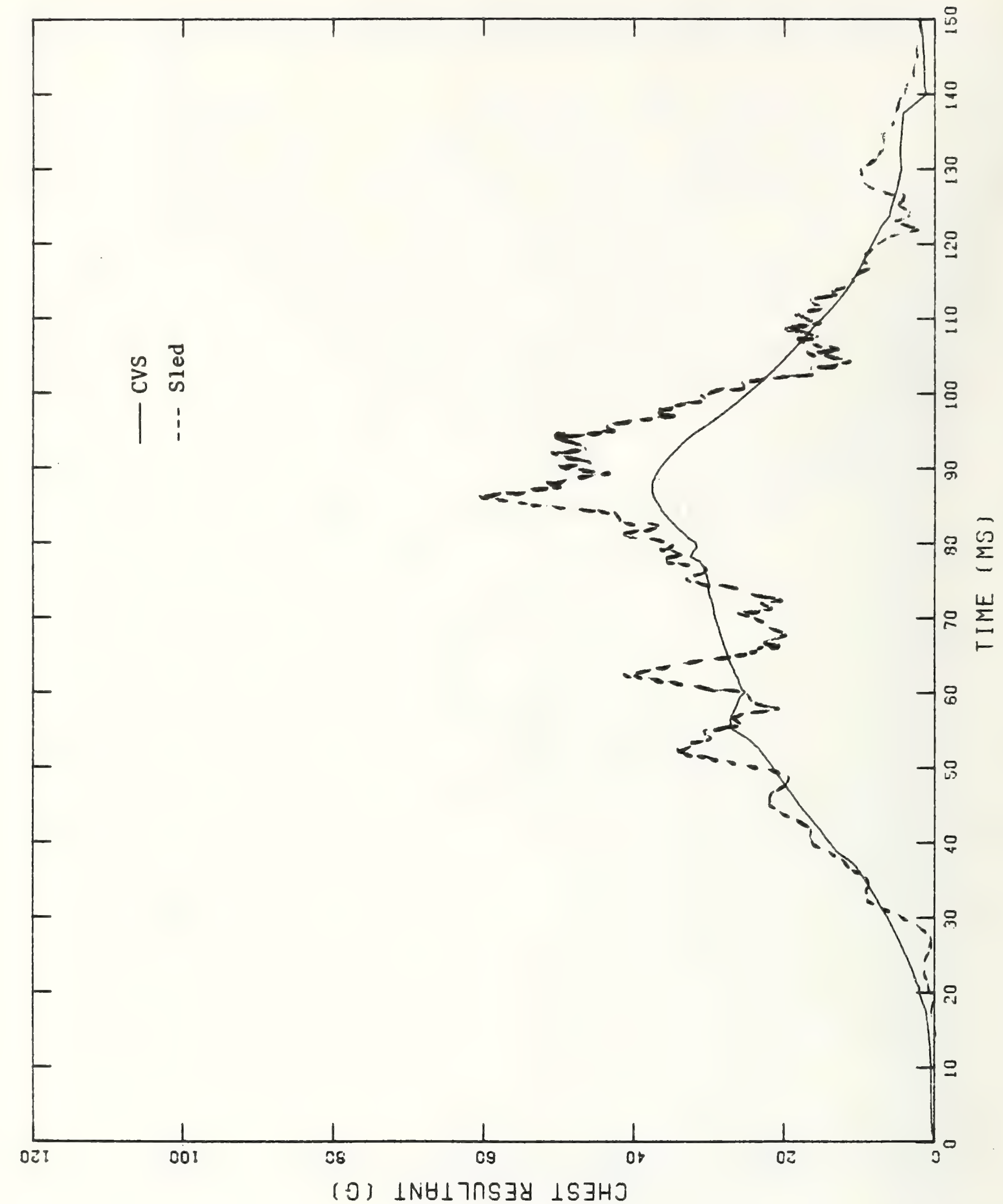
HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2027 (R2027C - TASK 4)



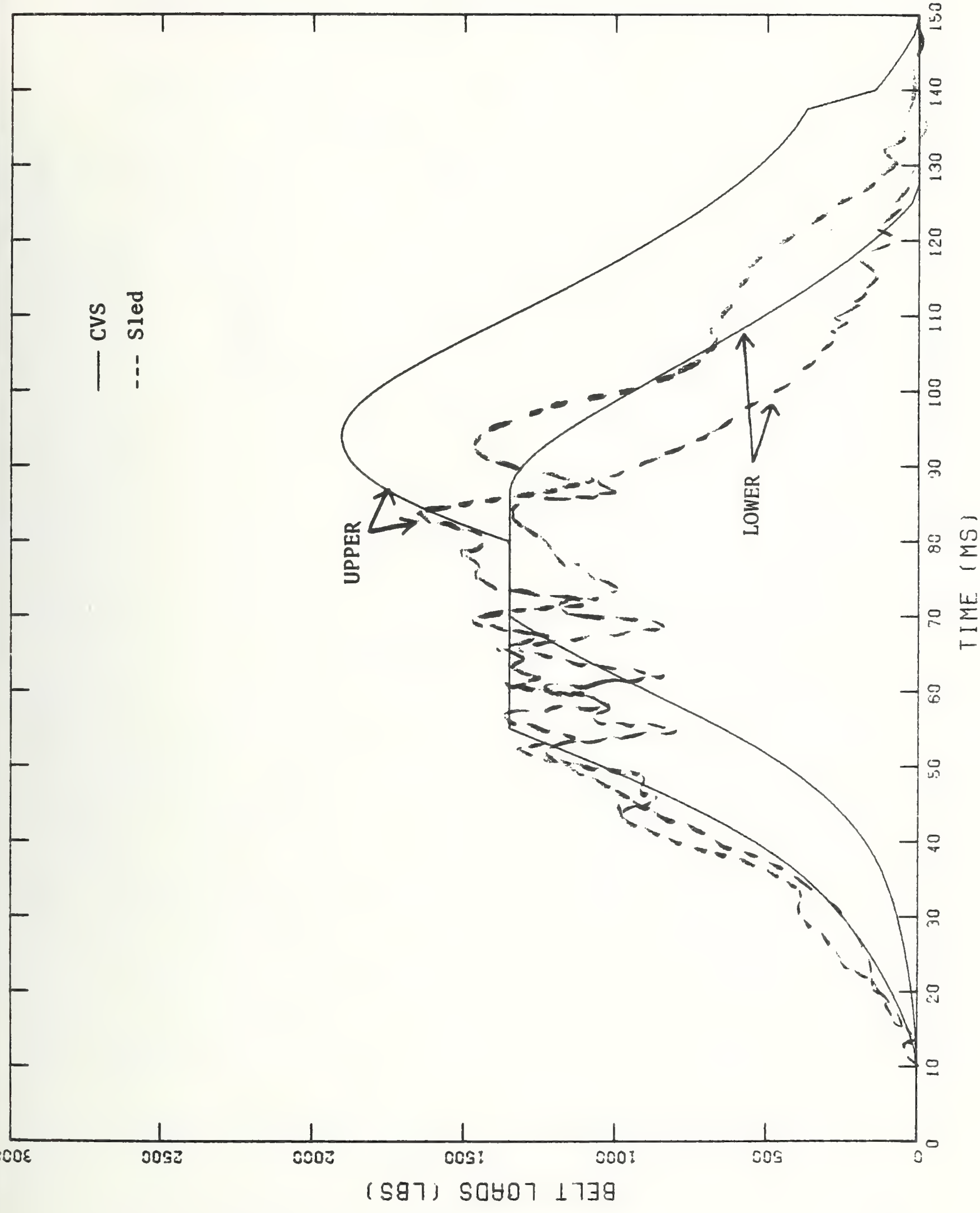
RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2027 (R2027C - TASK 4)



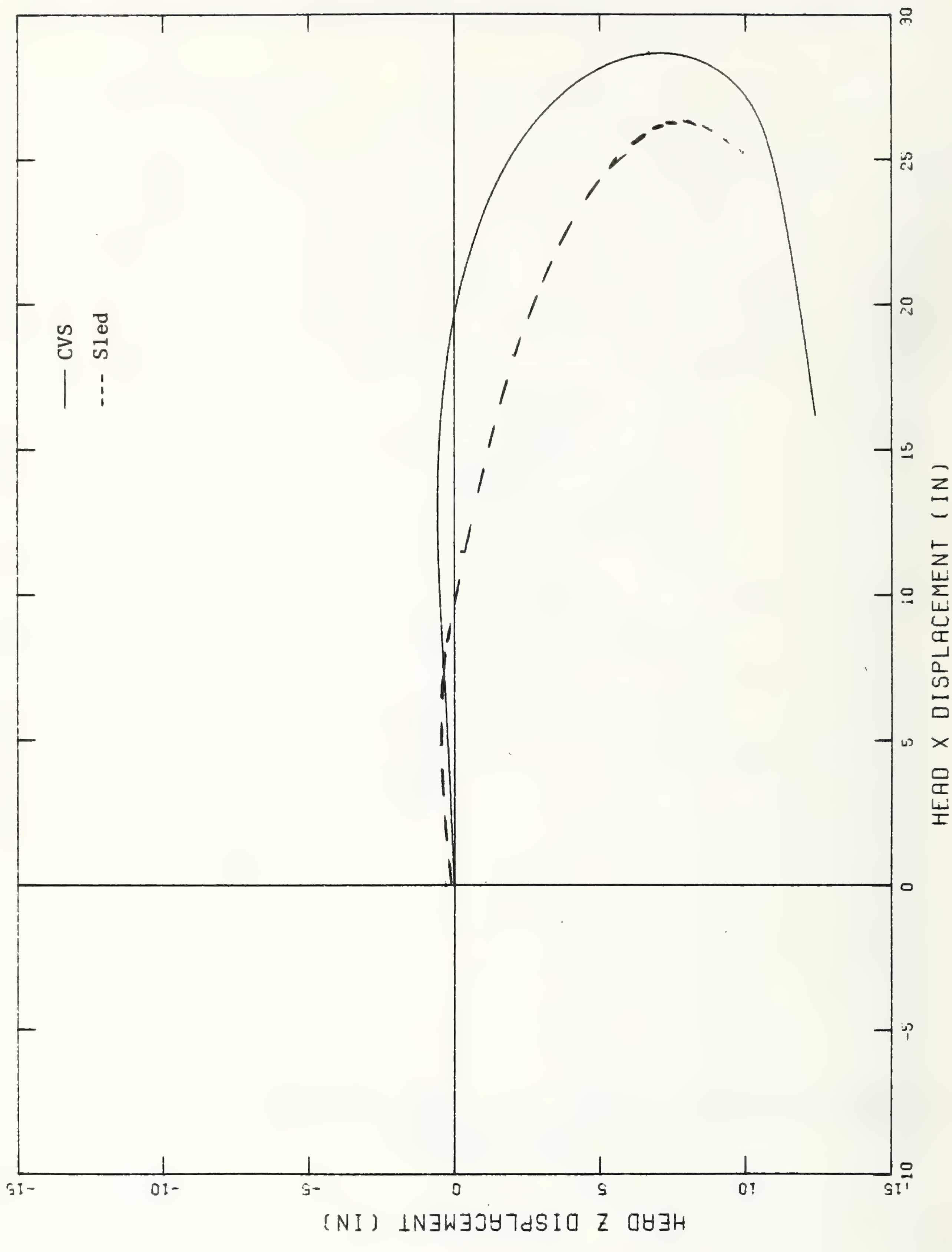
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2031 (R2031B - TASK 4)



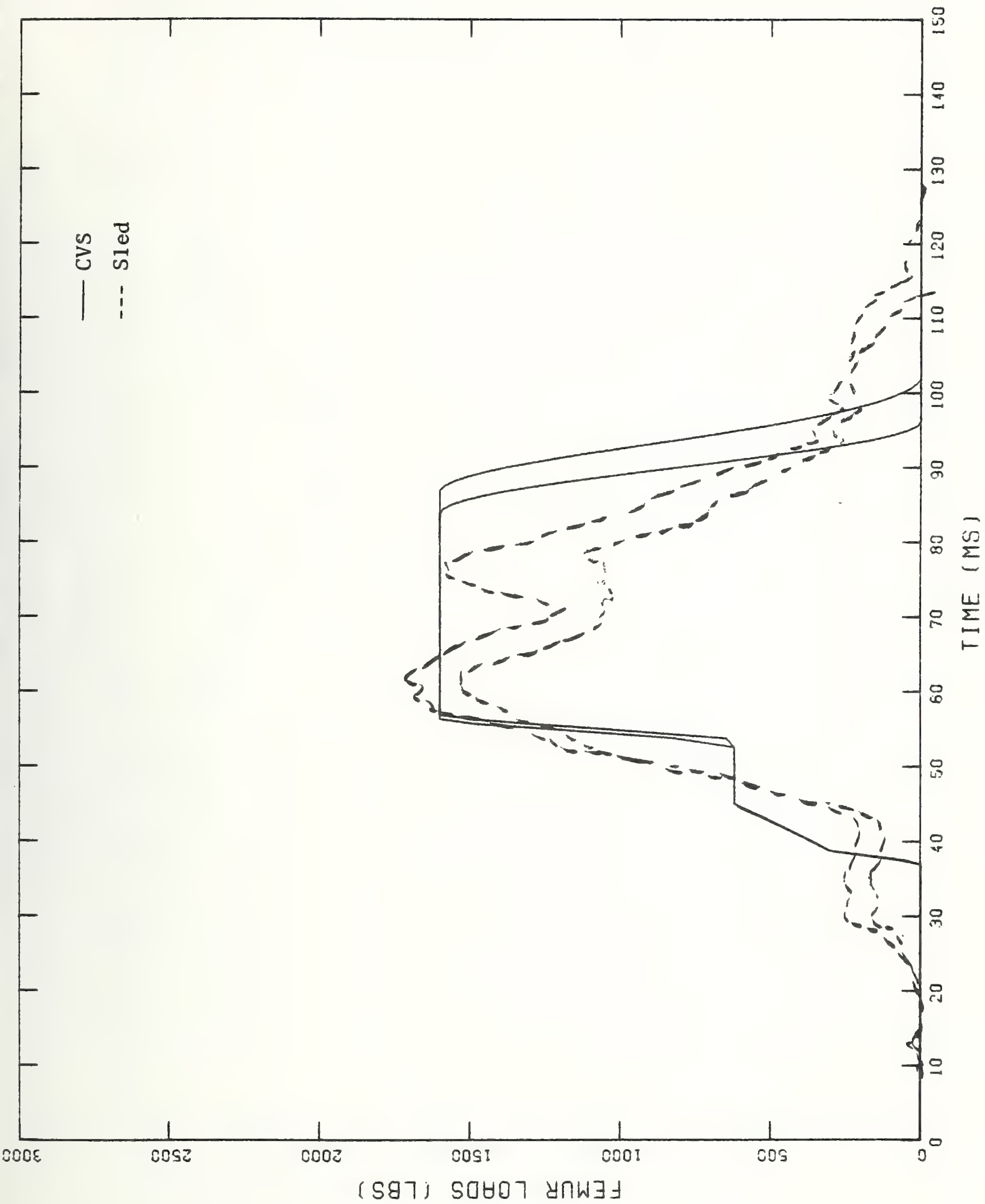
CHEST RESULTANT ACCELERATION VS.TIME
SIMULATION OF RUN 2031 (R2031B - TASK 4)



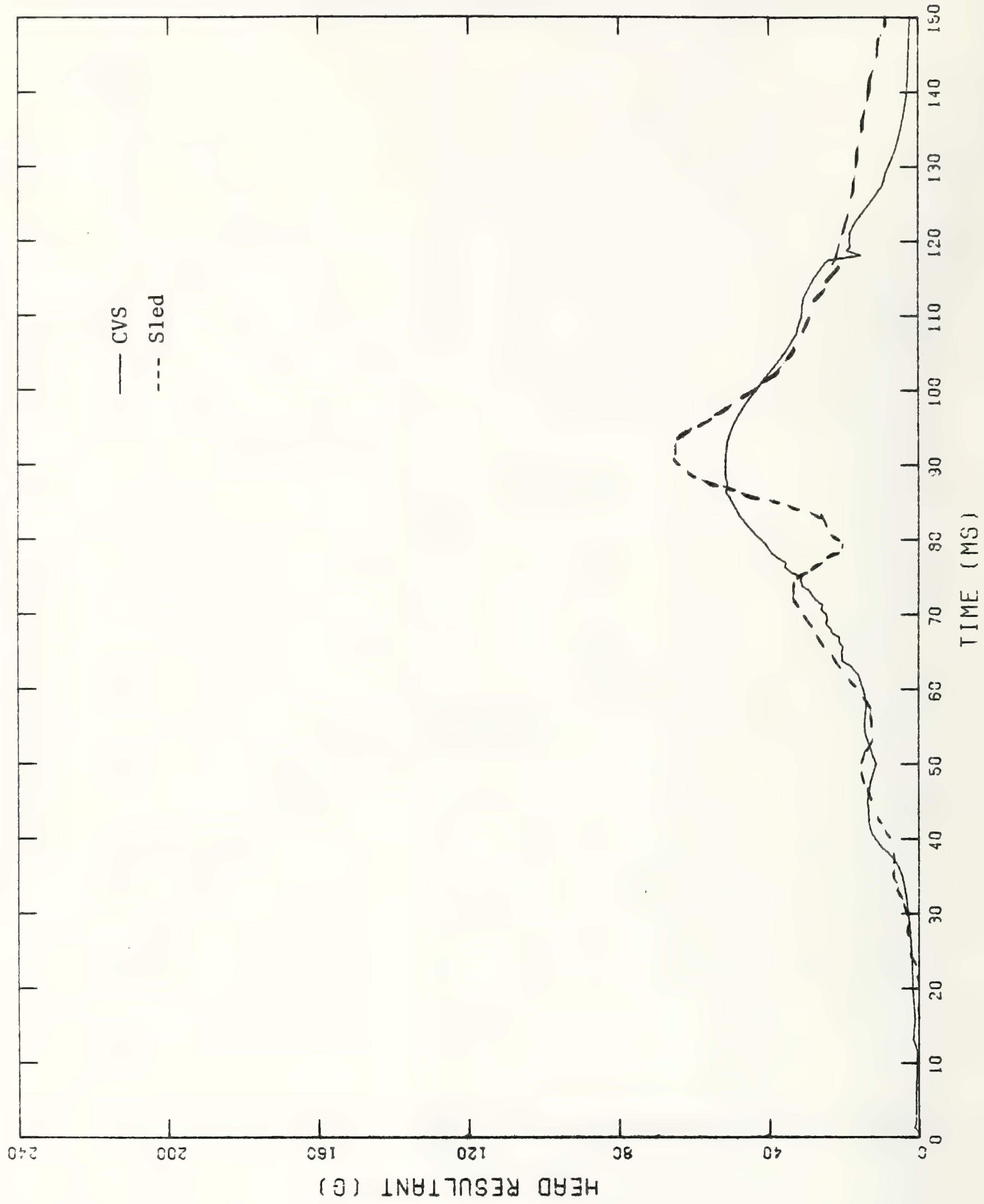
BELT LOADS VS. TIME
SIMULATION OF RUN 2031 (R2031B - TASK 4)



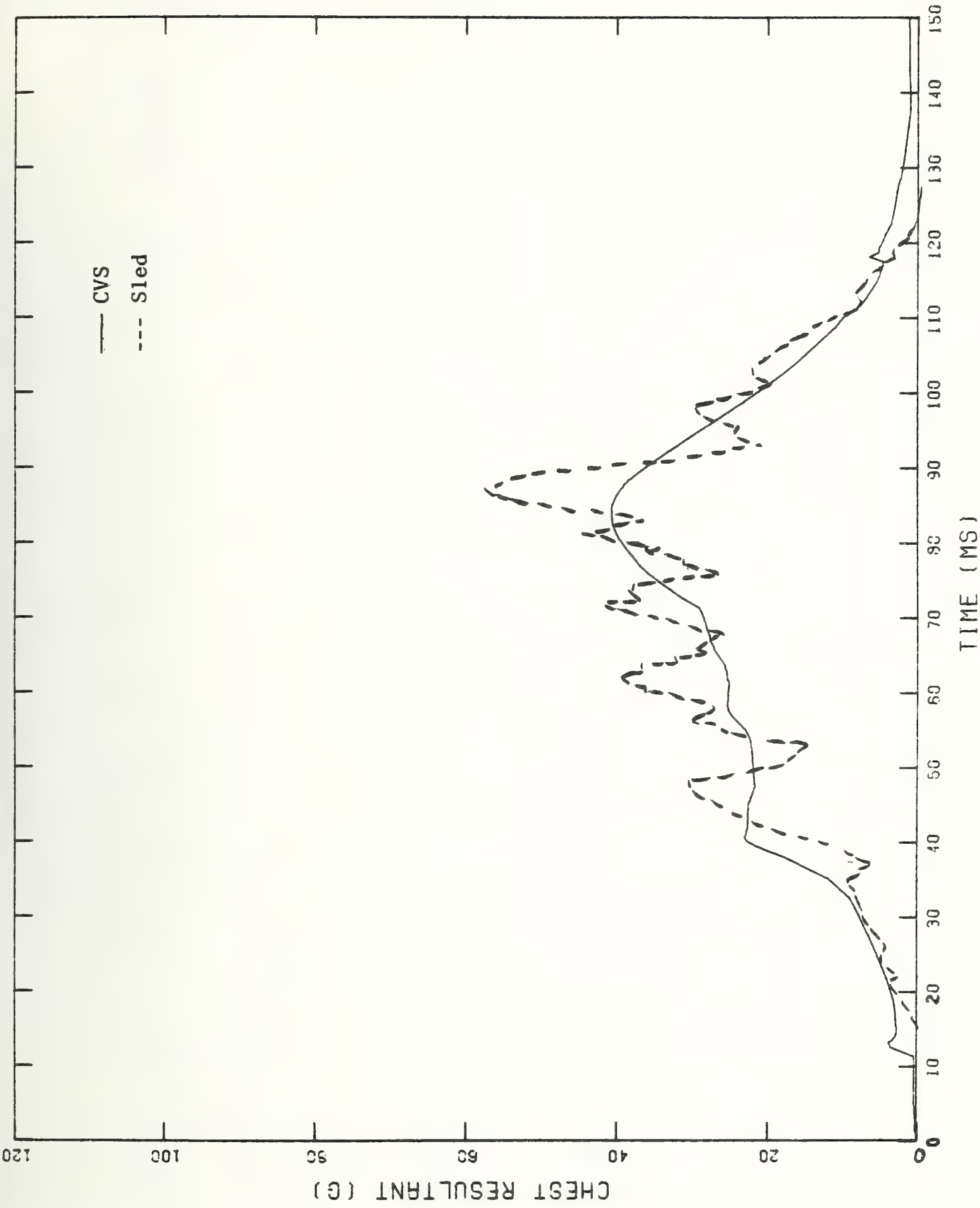
HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2031 (R2031B - TASK 4)



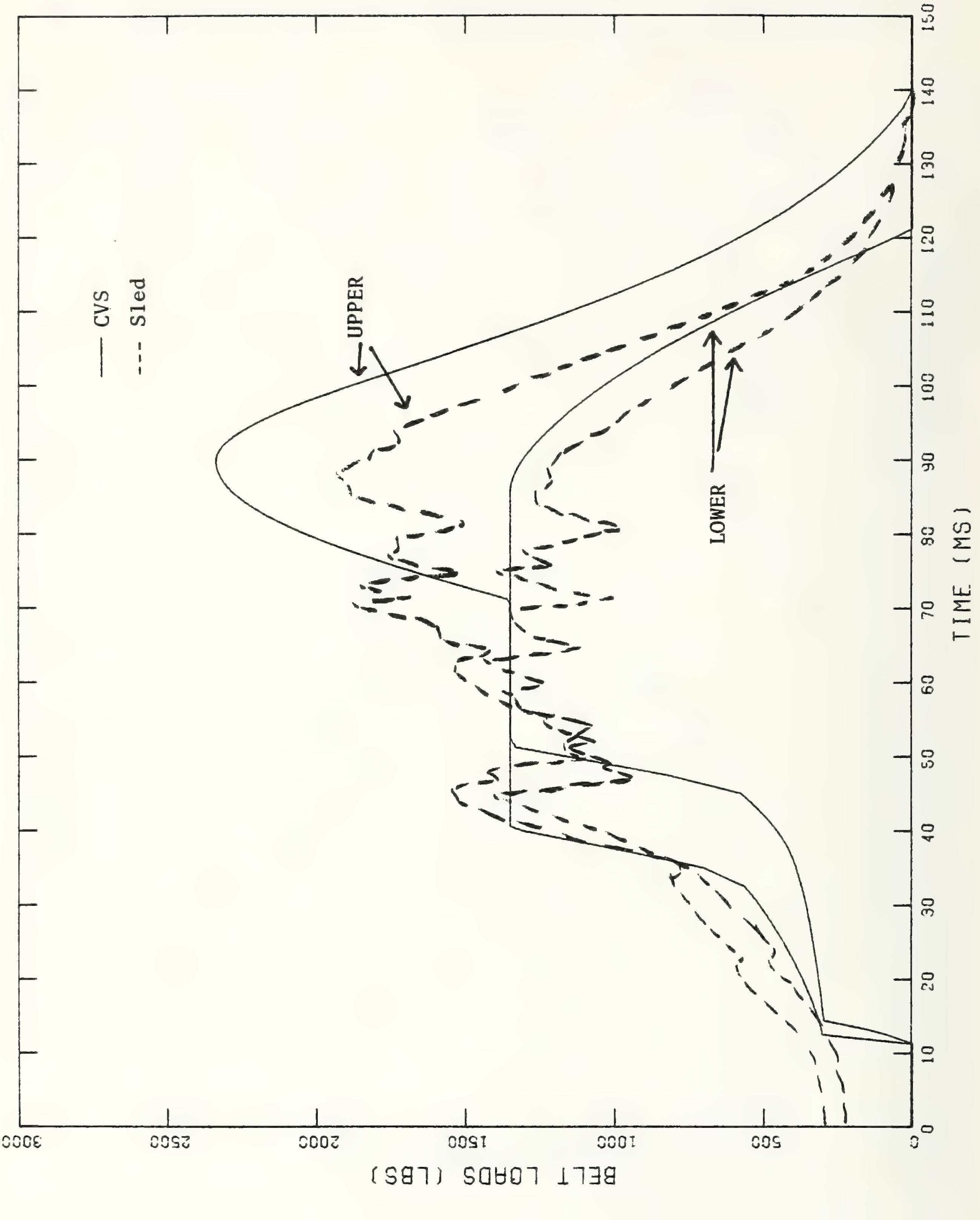
RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2031 (R2031B - TASK 4)



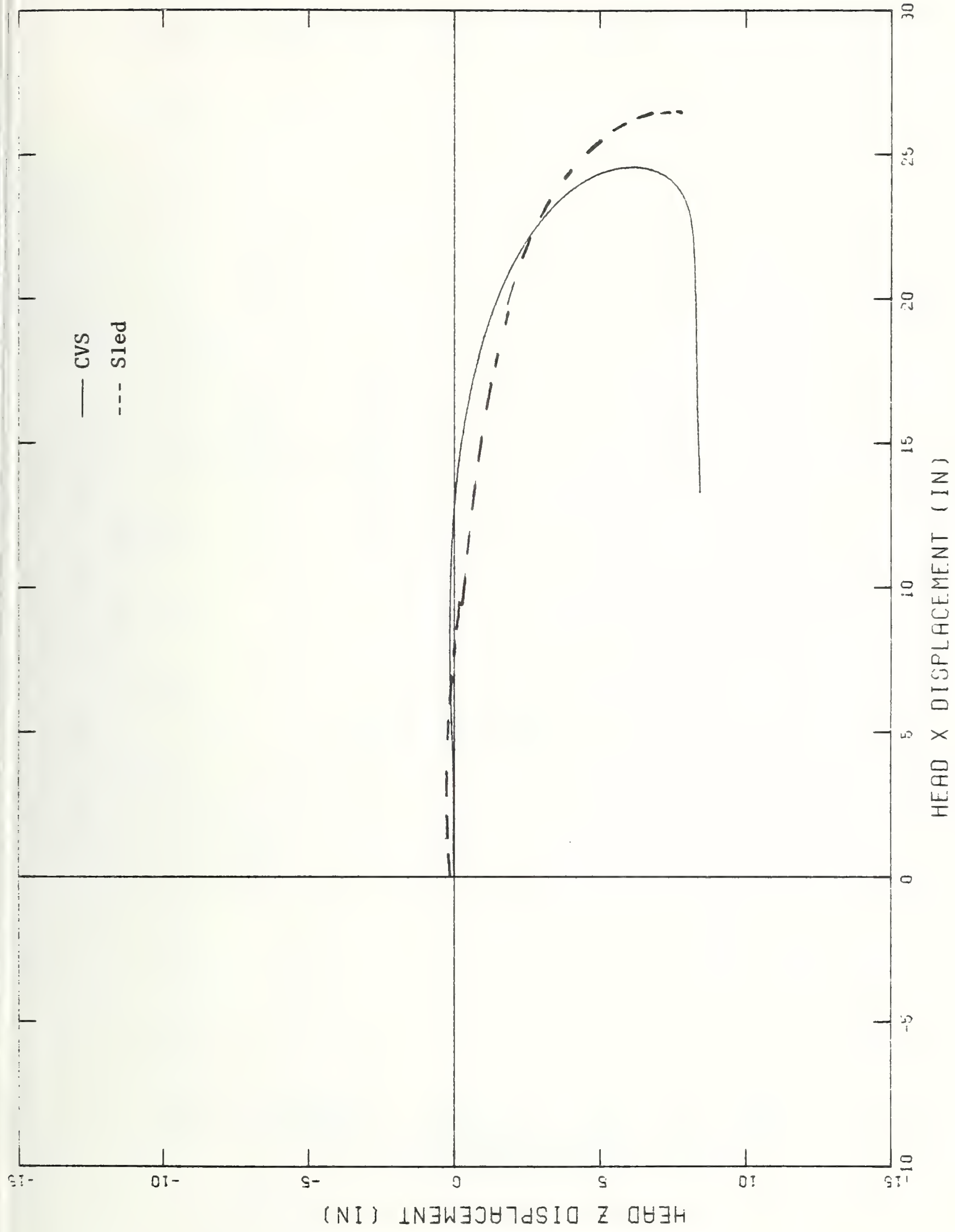
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2032 (R2032D - TASK 4)



CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2032 (R2032D - TASK 4)

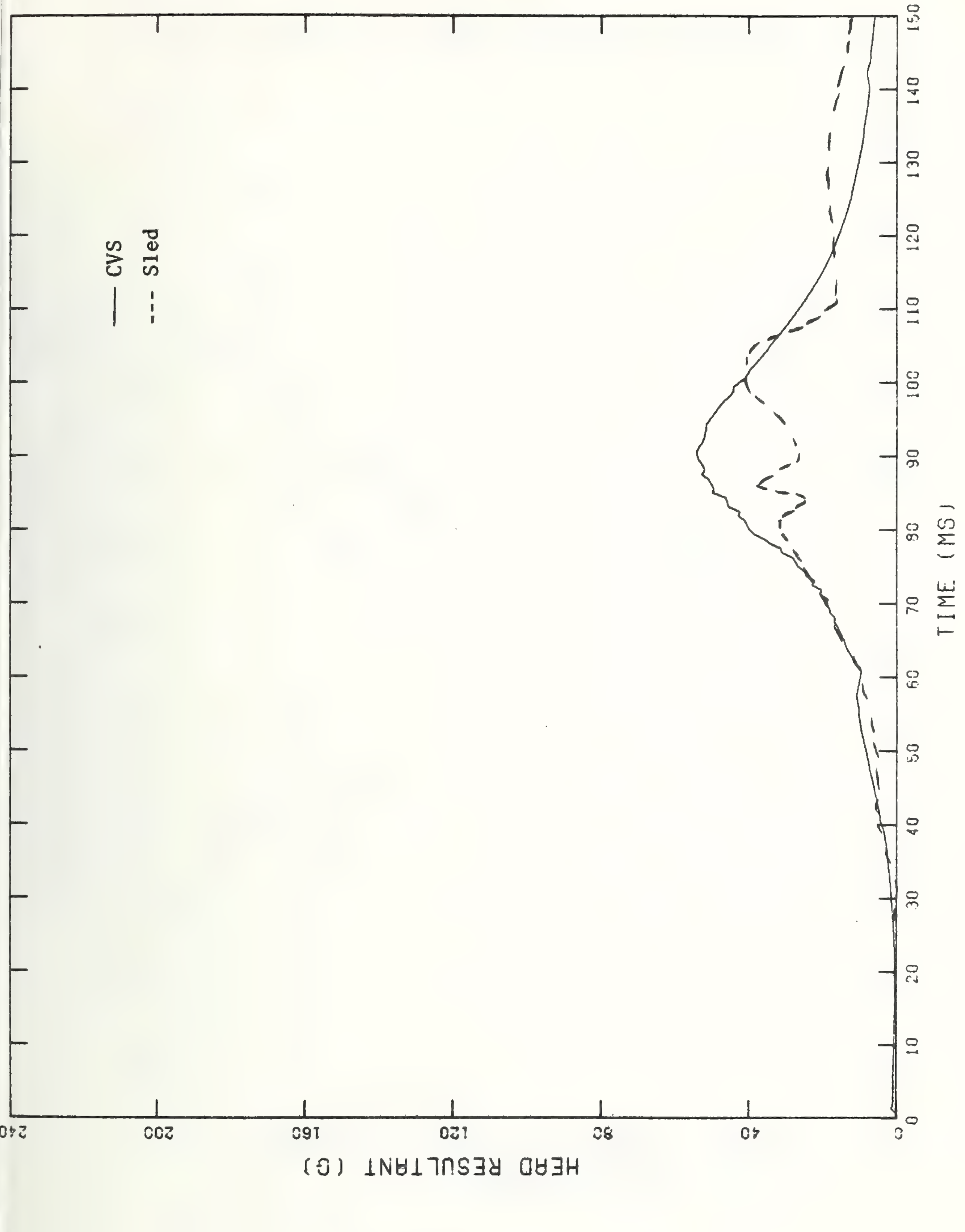


BELT LOADS VS. TIME
SIMULATION OF RUN 2032 (R2032D - TASK 4)

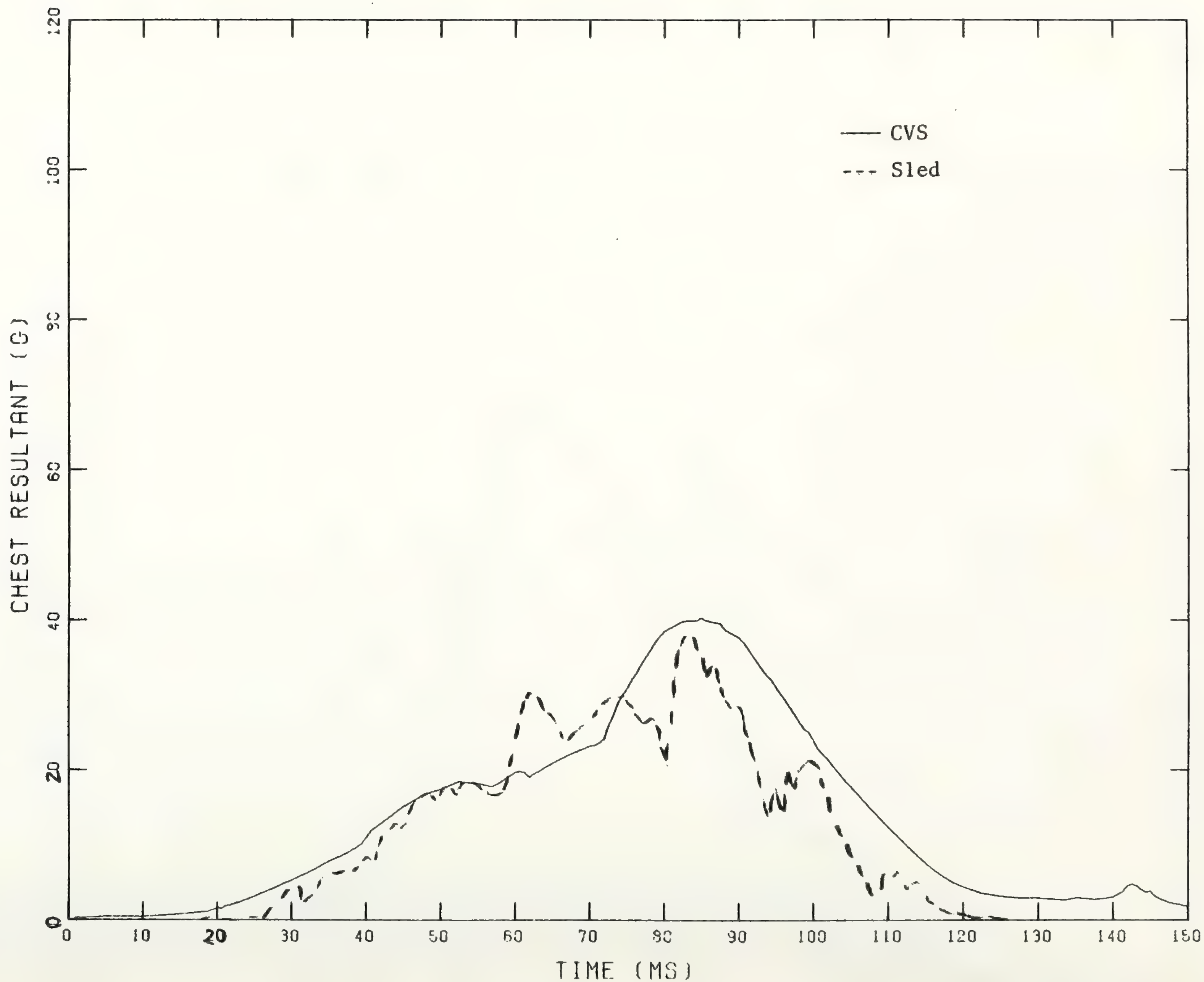


HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2032 (R2032D - TASK 4)

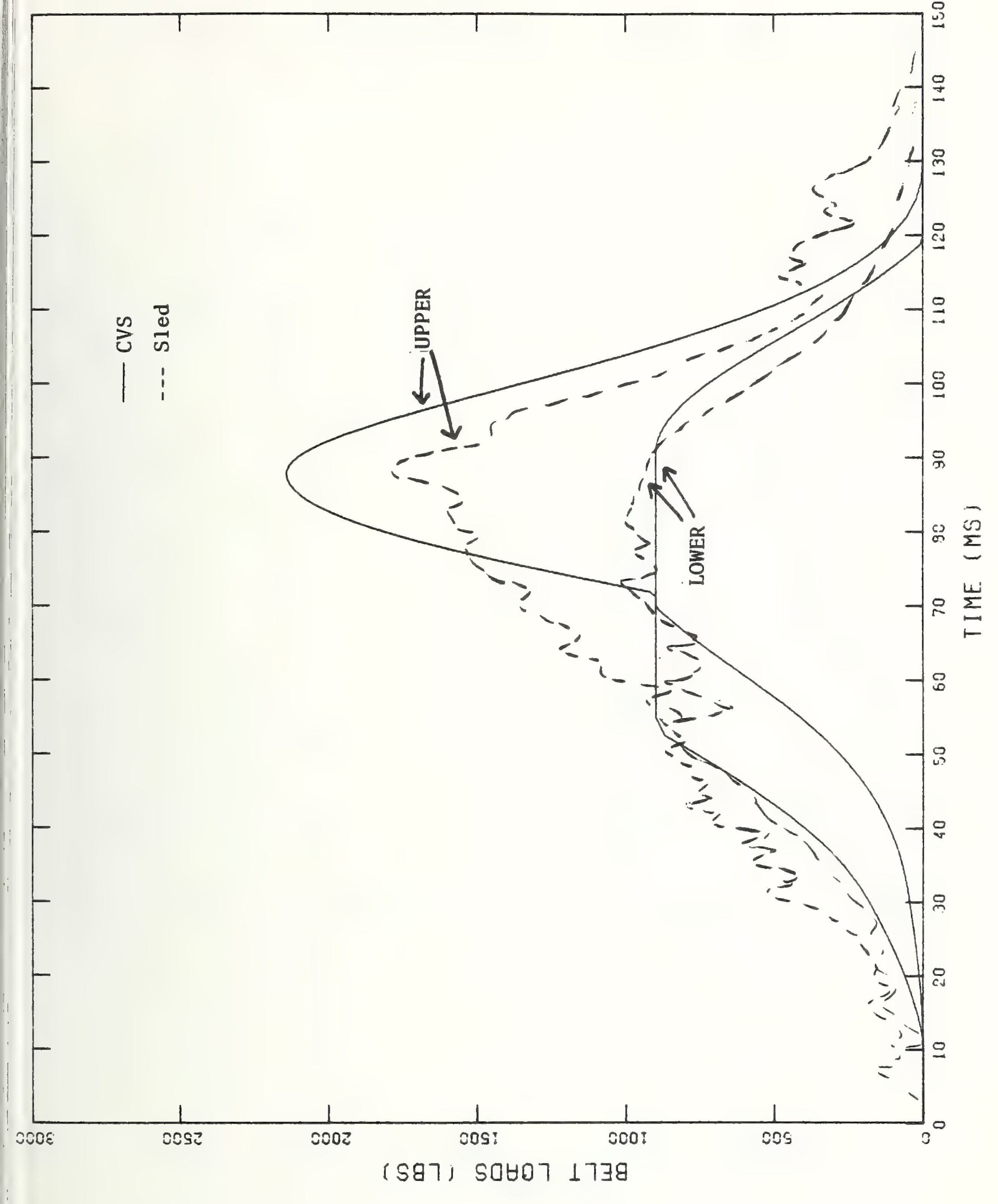
RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2032 (R2032D - TASK 4)



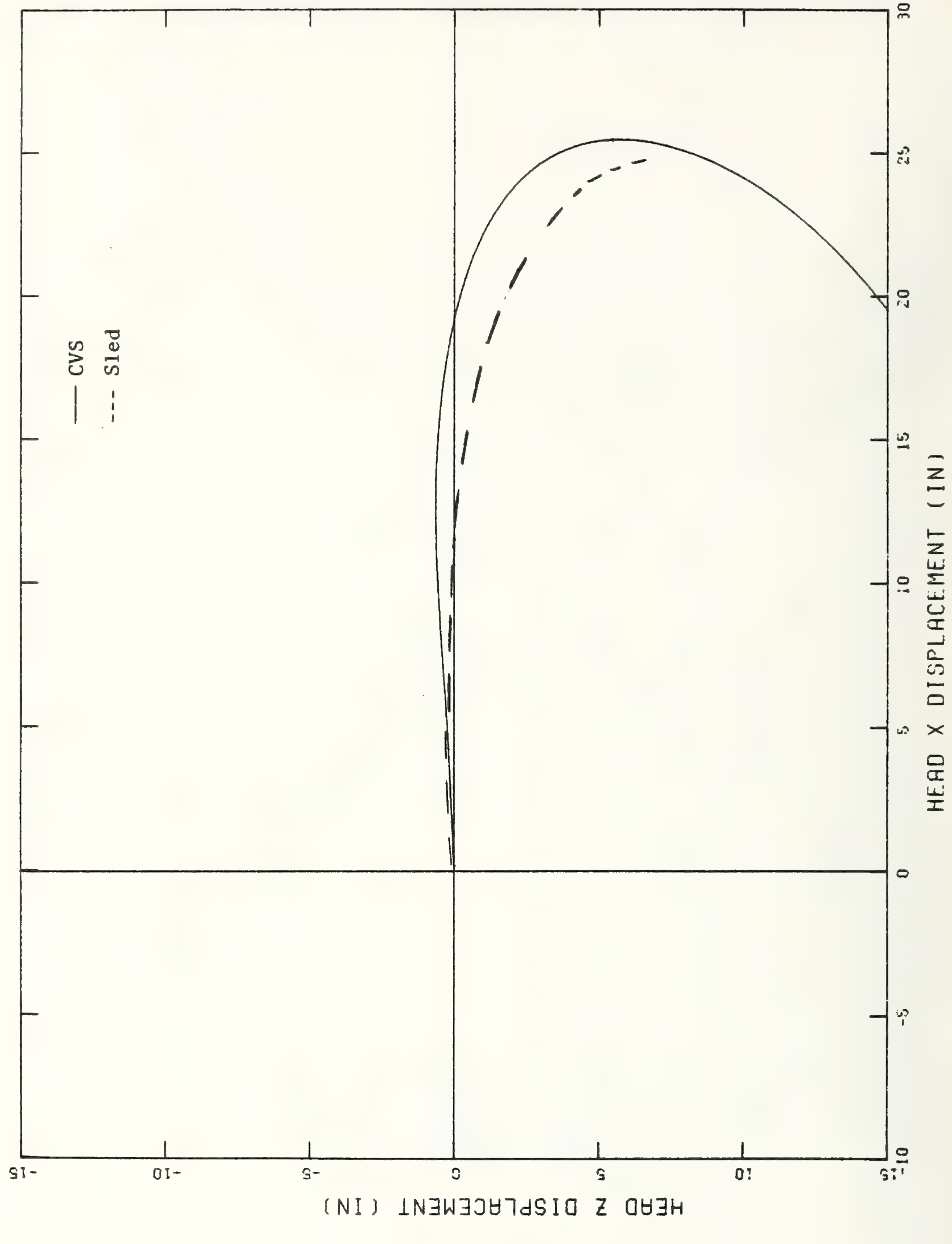
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2016 (R2016B - TASK 4)



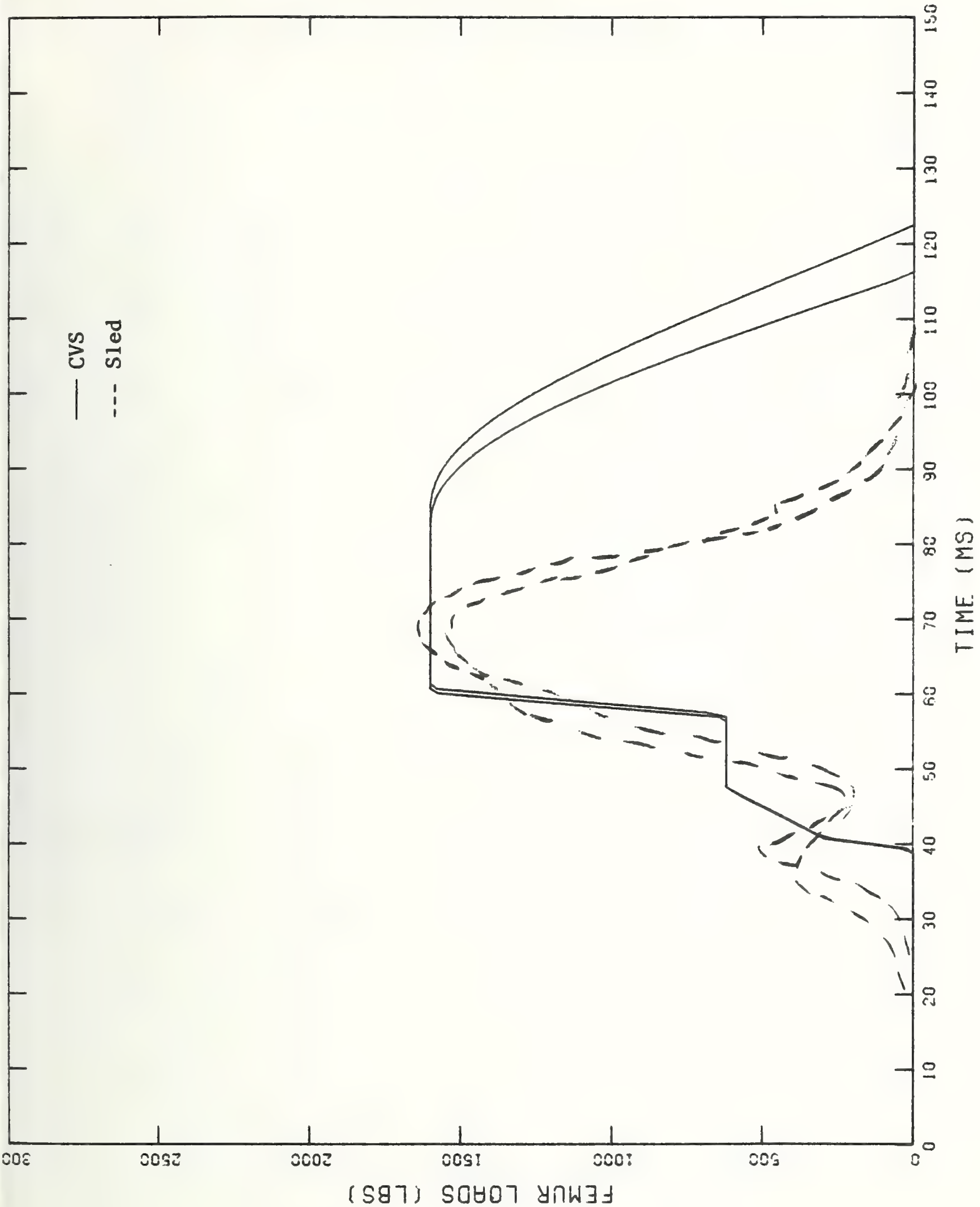
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2016 (R2016B - TASK 4)



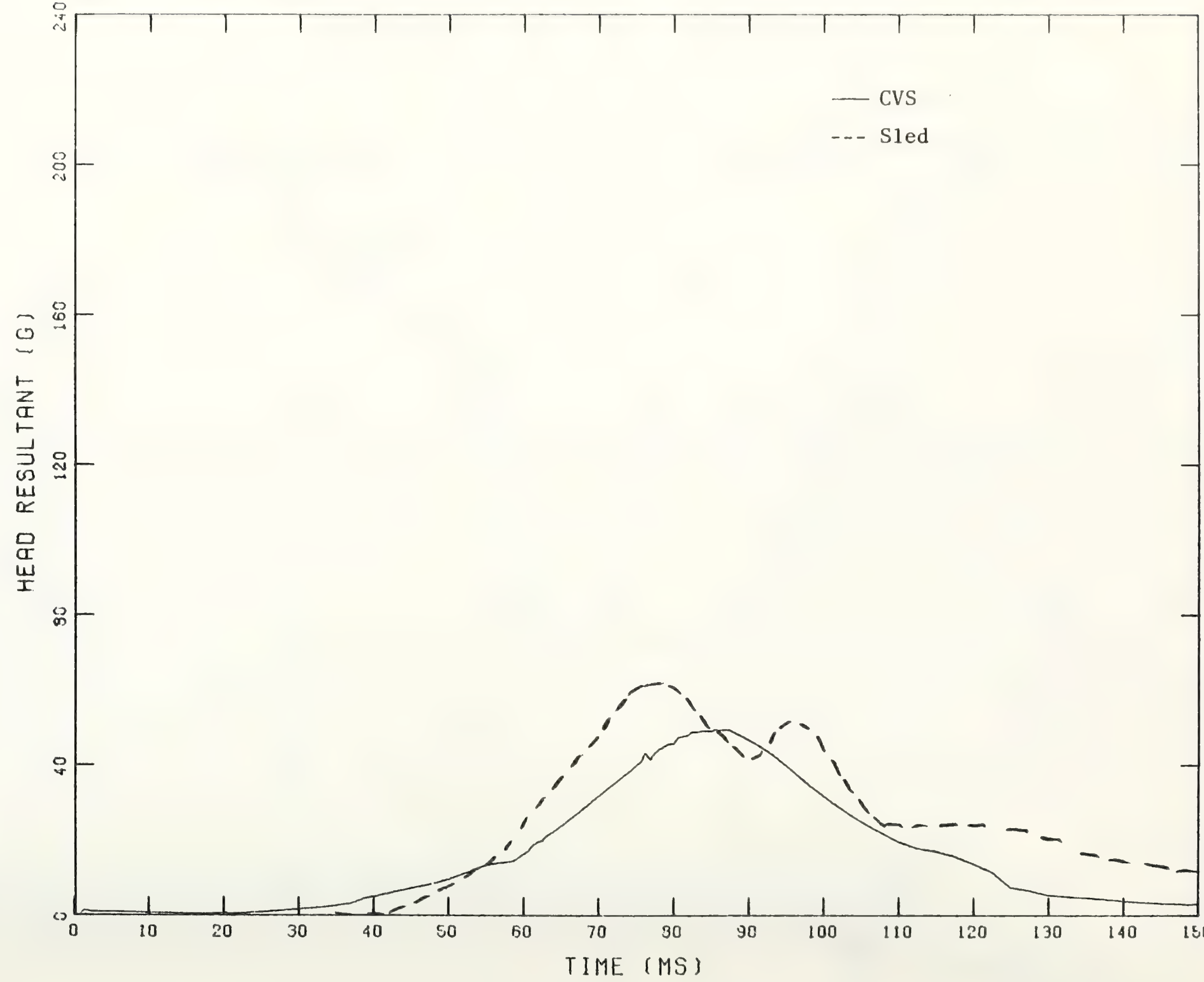
BELT LOADS VS. TIME
SIMULATION OF RUN 2016 (R2016B - TASK 4)



HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2016 (R2016B - TASK 4)

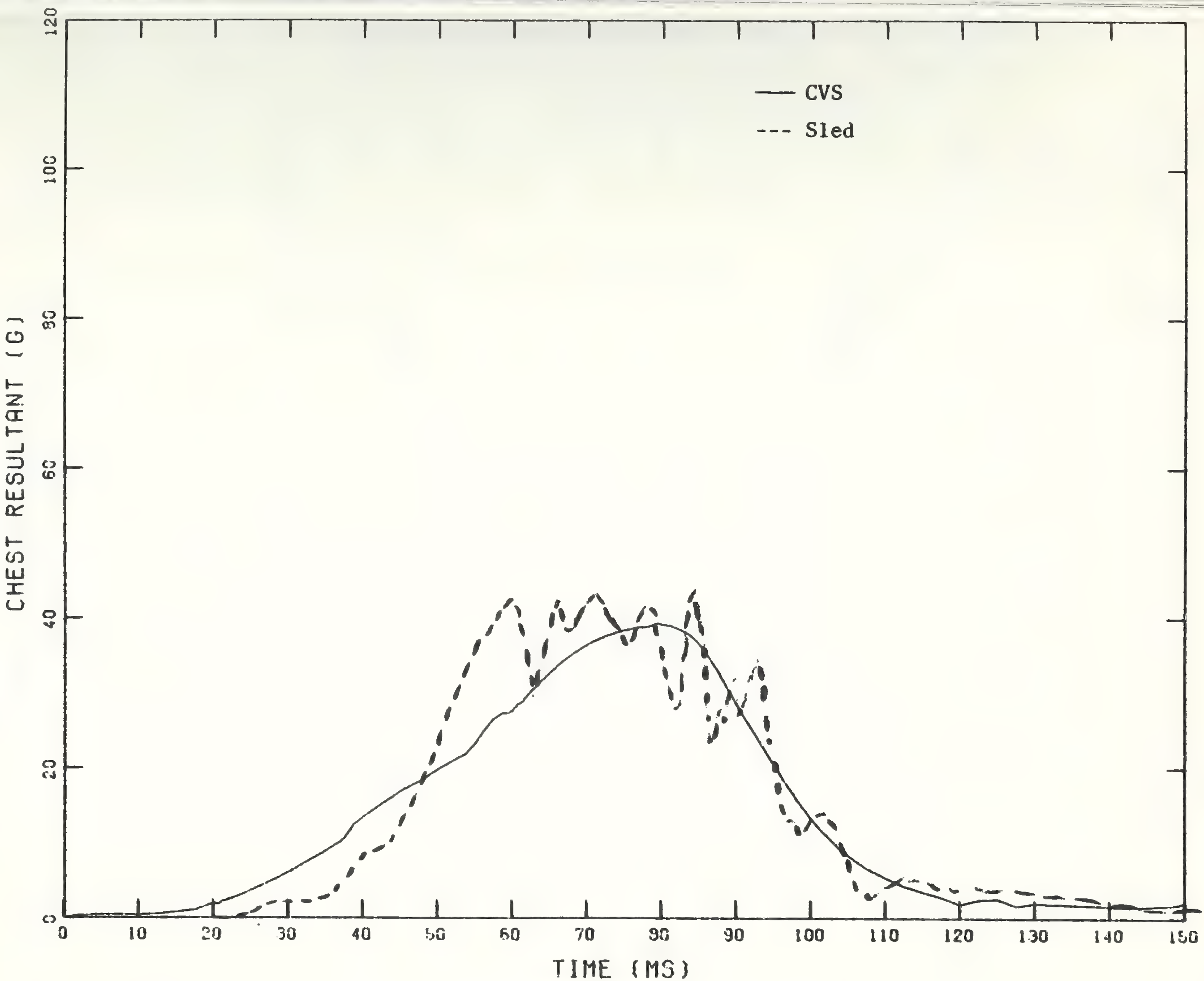


RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2016 (R2016B - TASK 4)

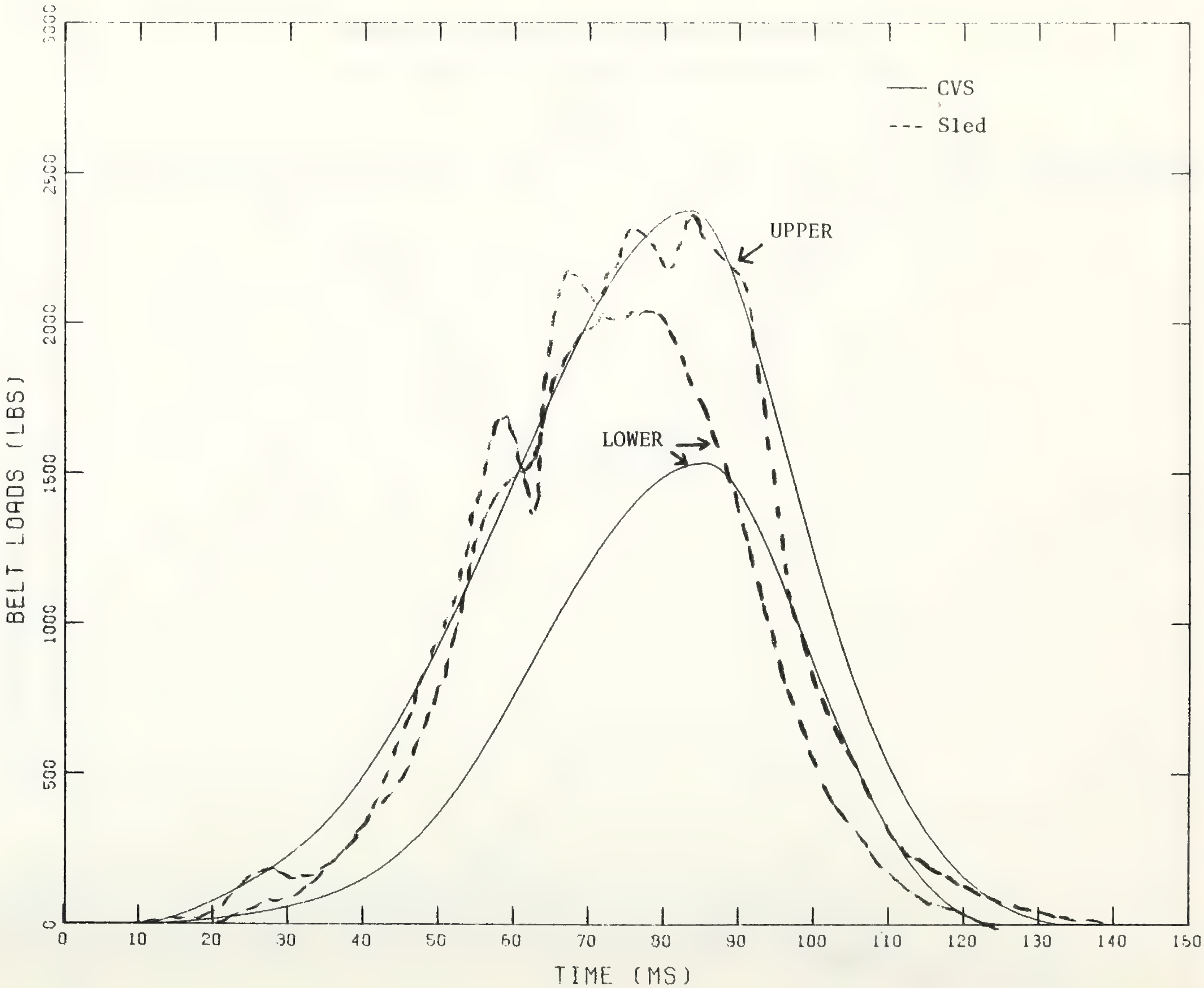


HEAD RESULTANT ACCELERATION VS.TIME

SIMULATION OF RUN 2201 (R2201A - TASK 4)

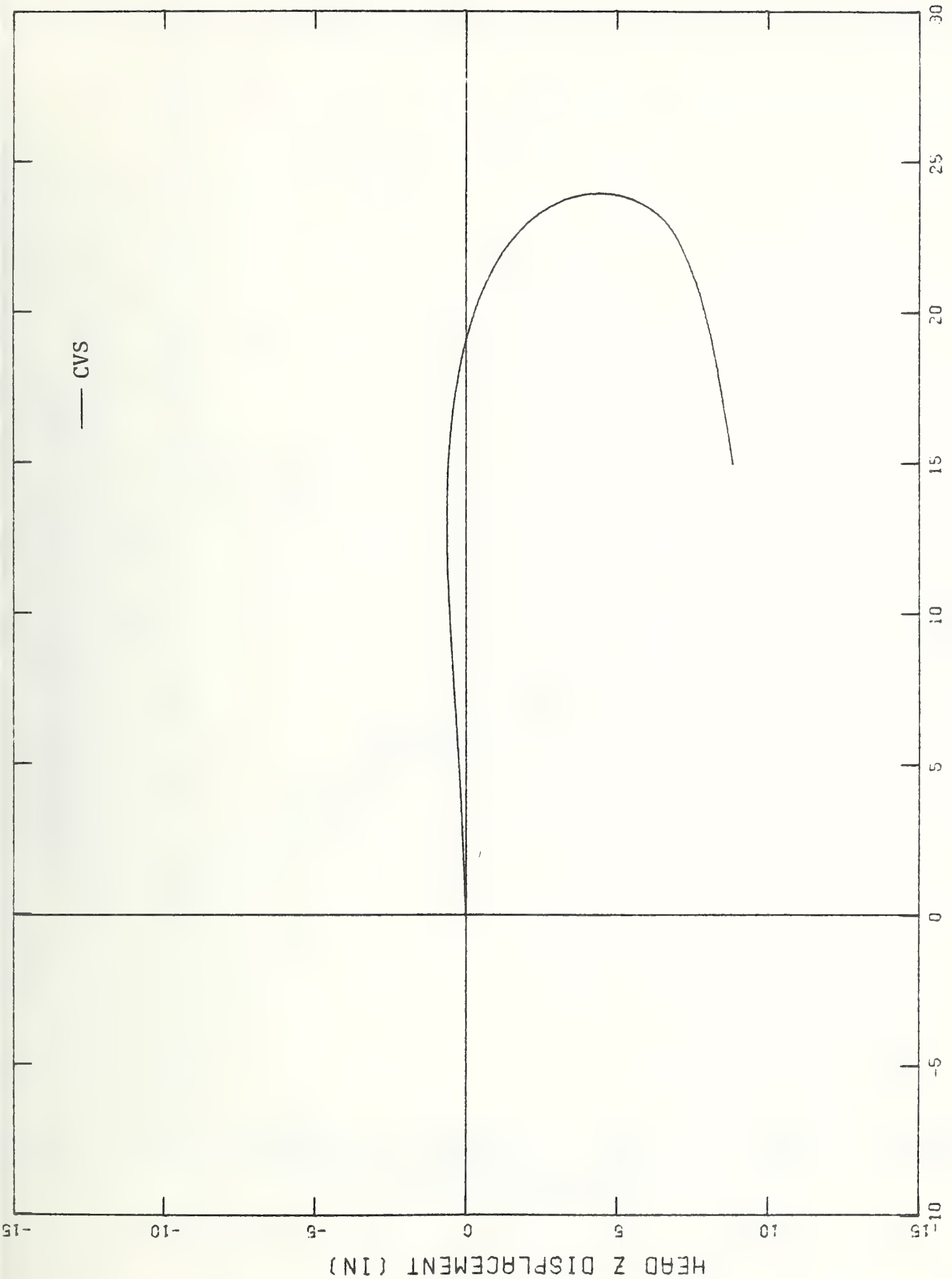


CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2201 (R2201A - TASK 4)

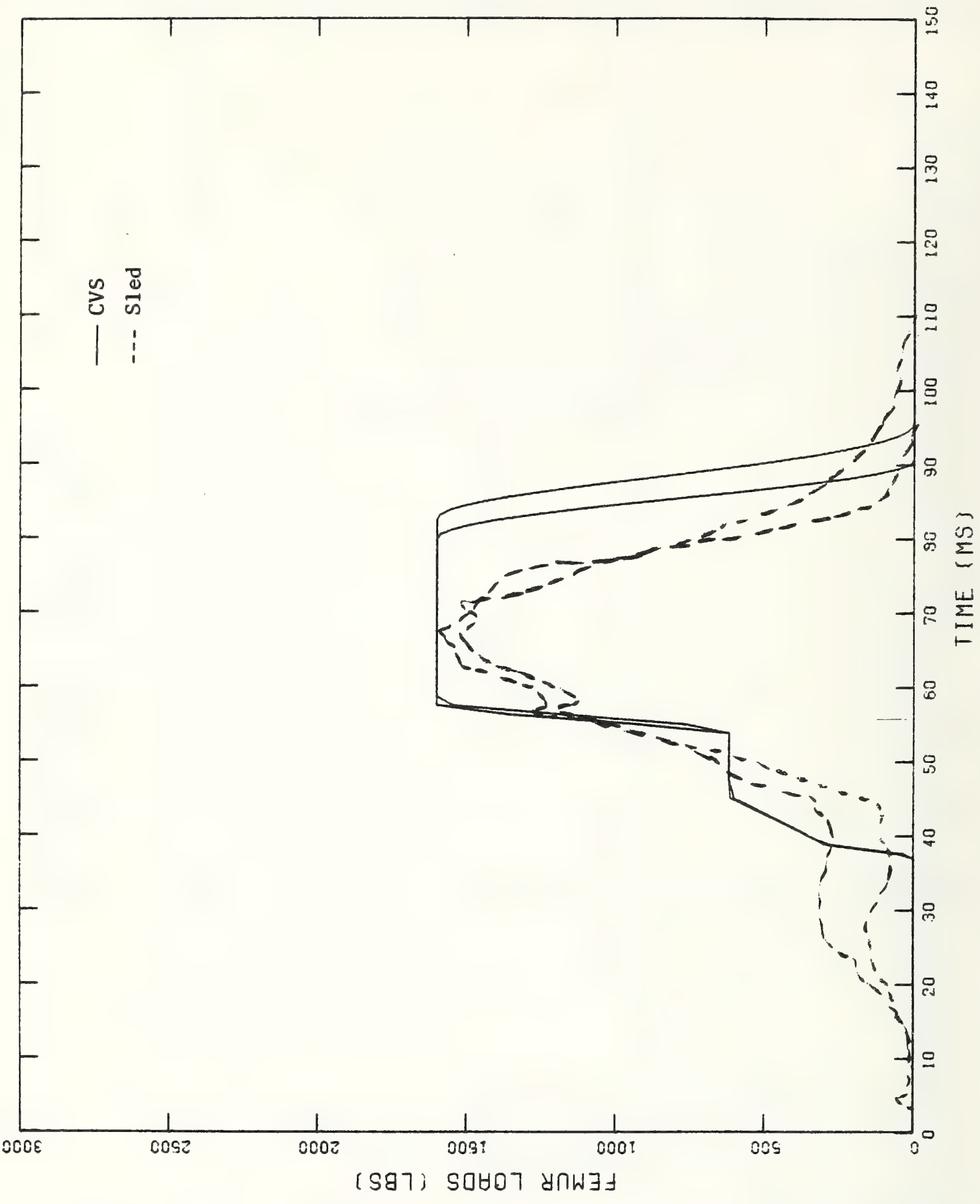


BELT LOADS VS. TIME

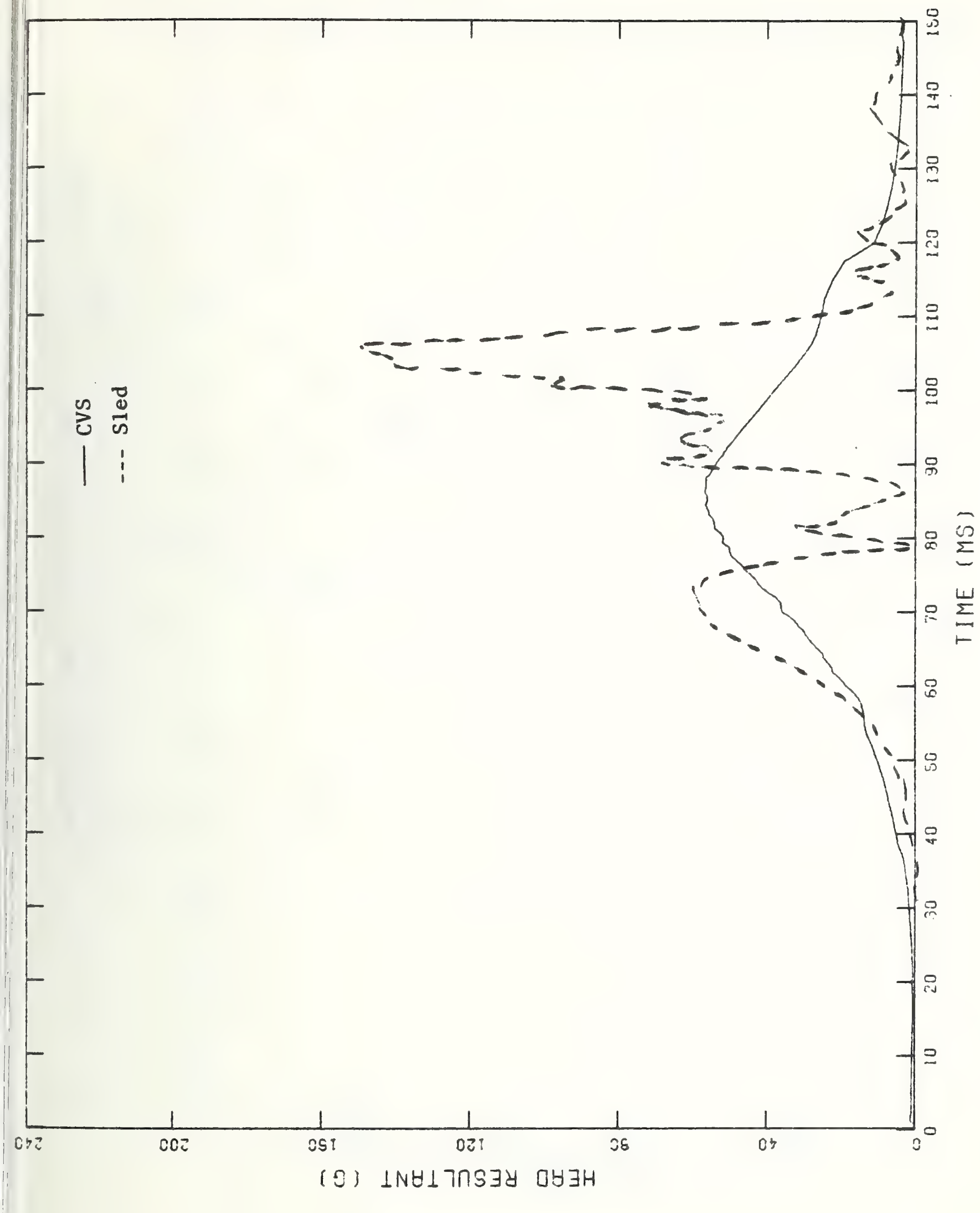
SIMULATION OF RUN 2201 (R2201A - TASK 4)



HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2201 (R2201A - TASK 4)

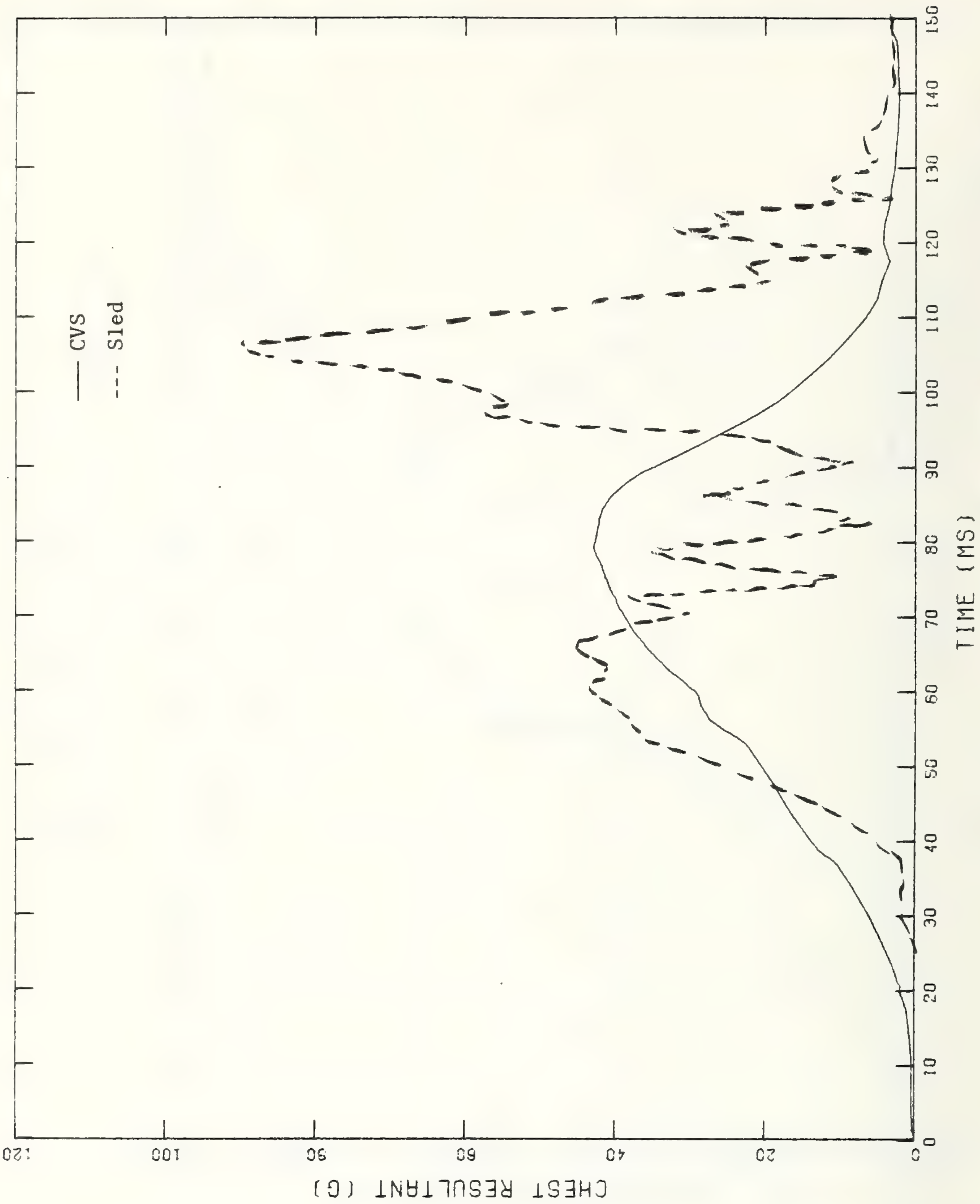


RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2201 (R2201A - TASK 4)



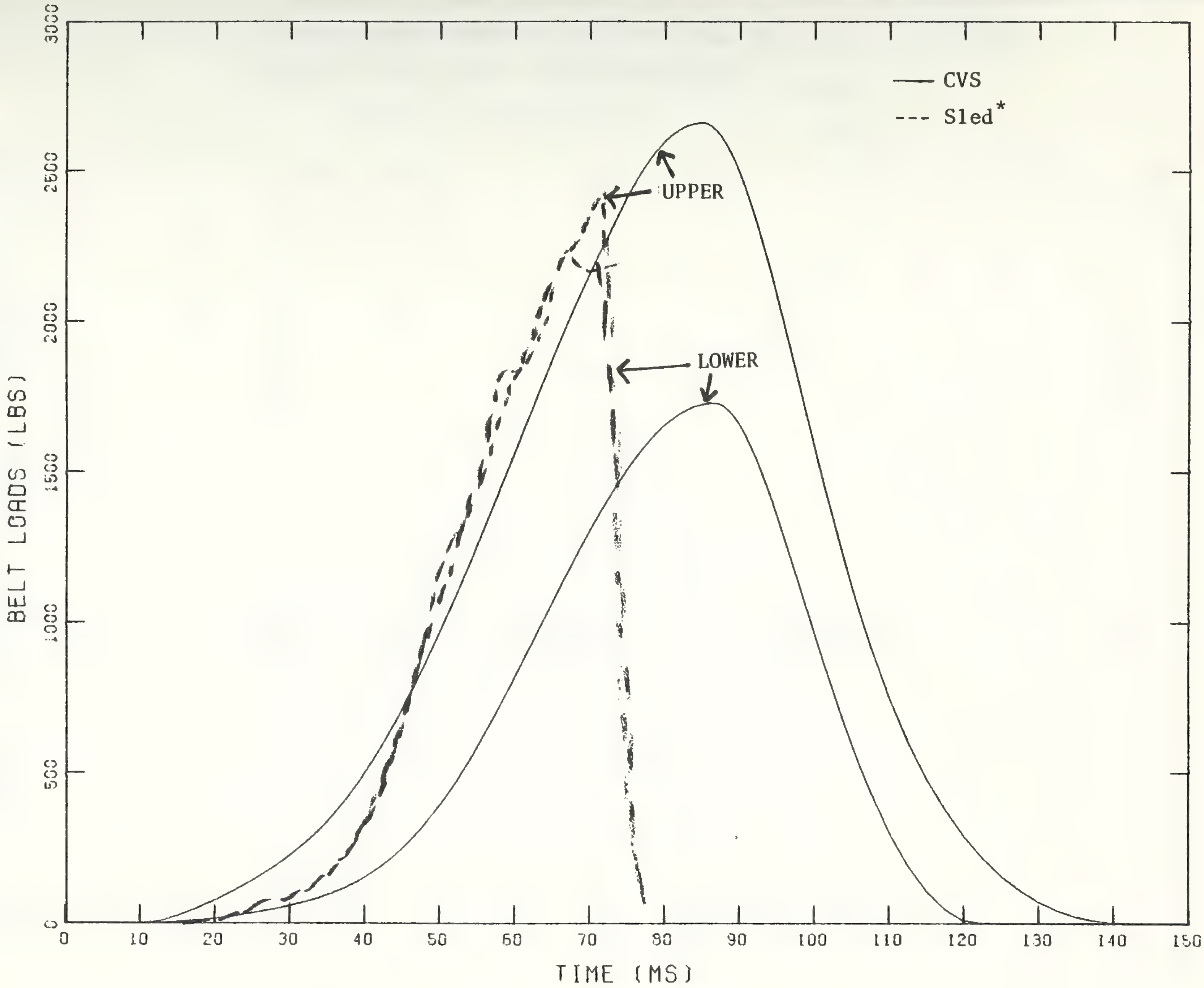
HEAD RESULTANT ACCELERATION VS. TIME

SIMULATION OF RUN 2202 (R2202A - TASK 4)



CHEST RESULTANT ACCELERATION VS. TIME

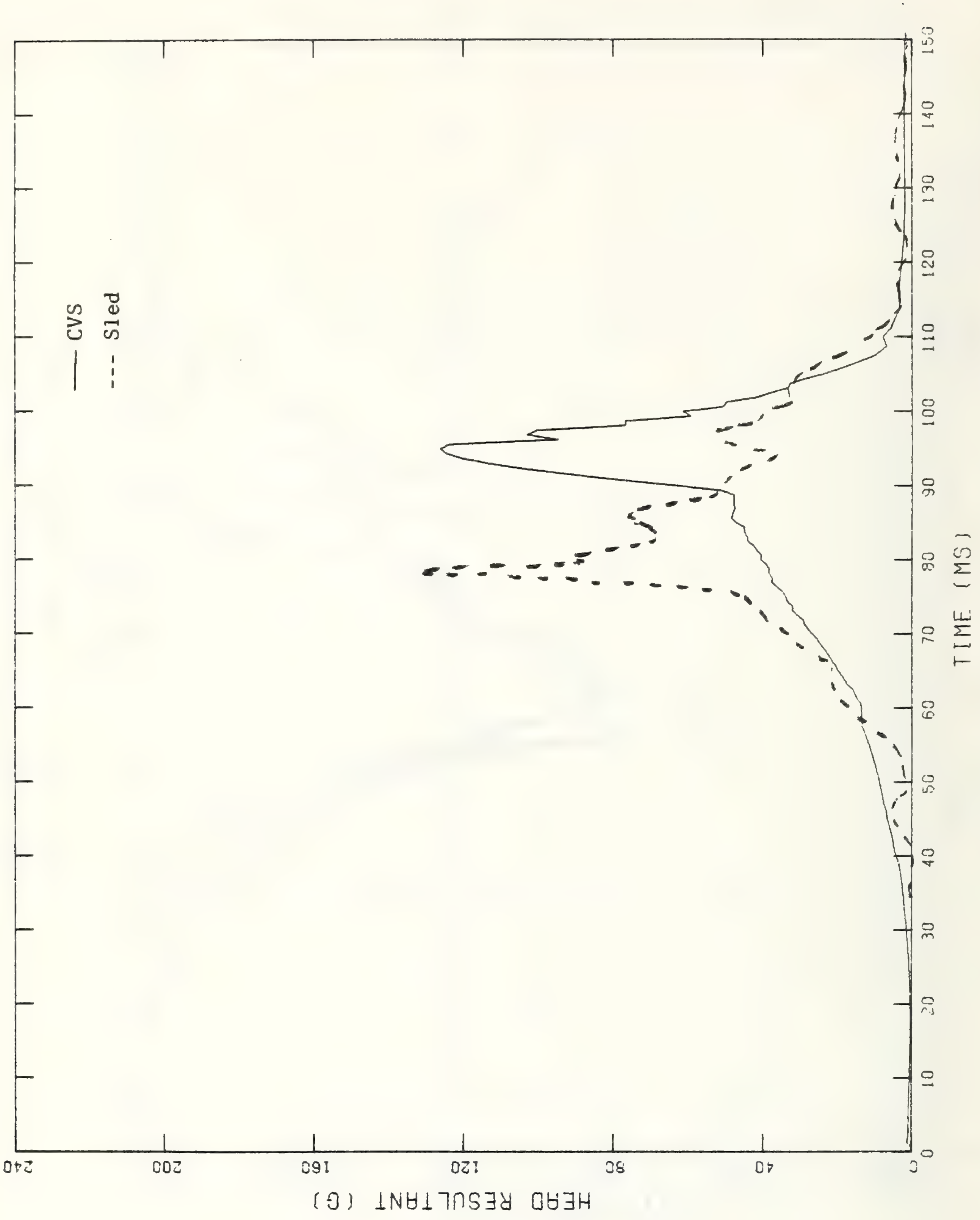
SIMULATION OF RUN 2202 (R2202A - TASK 4)



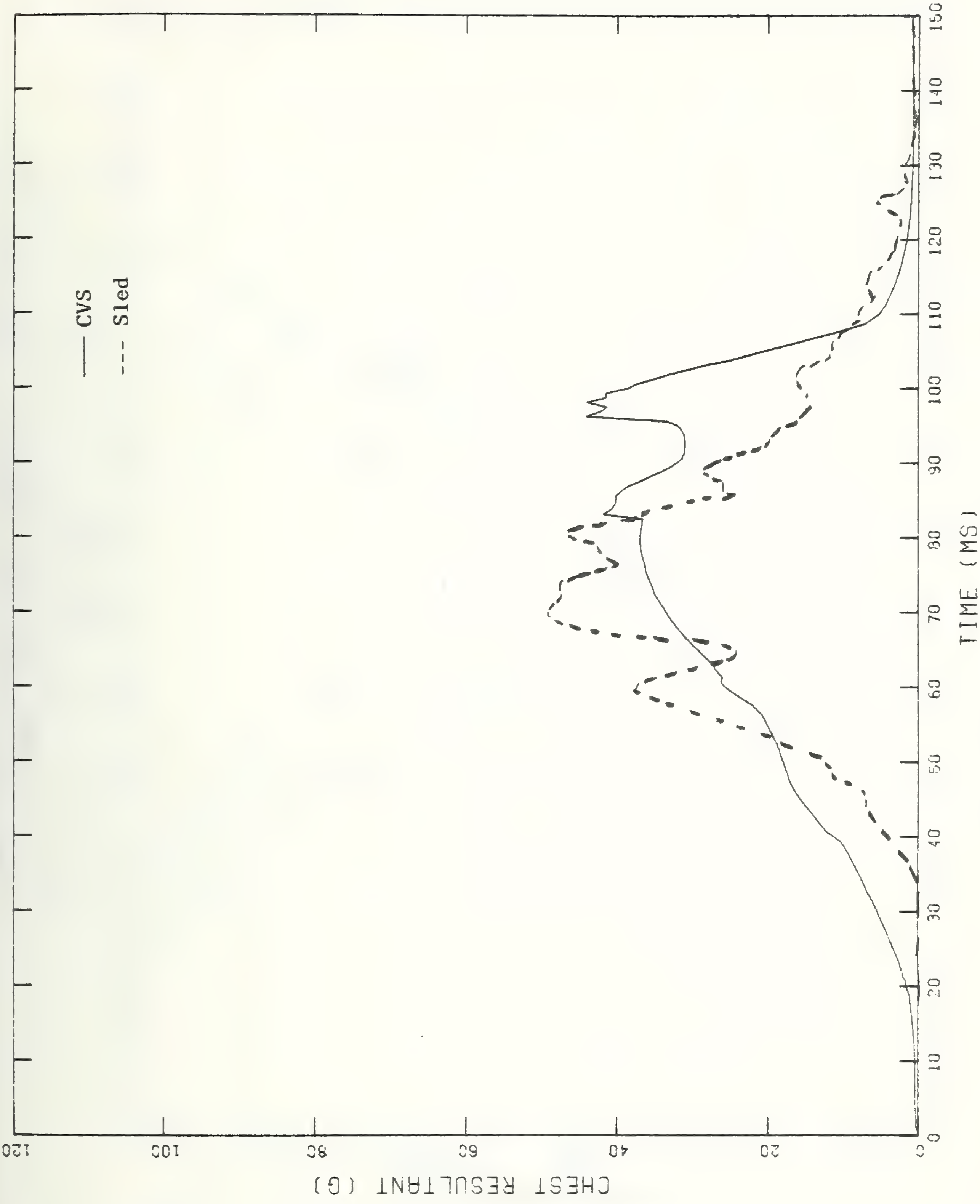
BELT LOADS VS. TIME

SIMULATION OF RUN 2202 (R2202A - TASK 4)

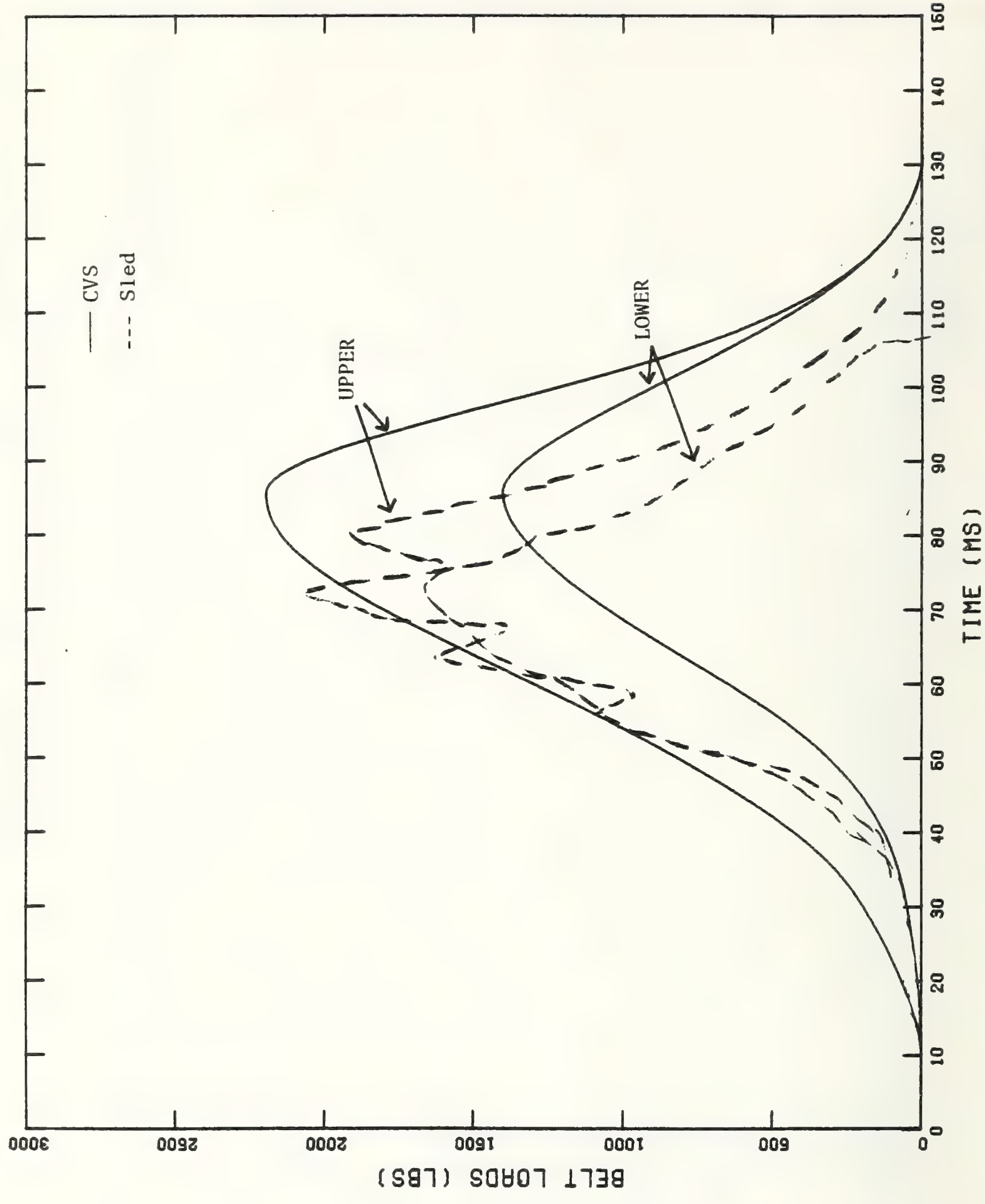
*BELT BROKE



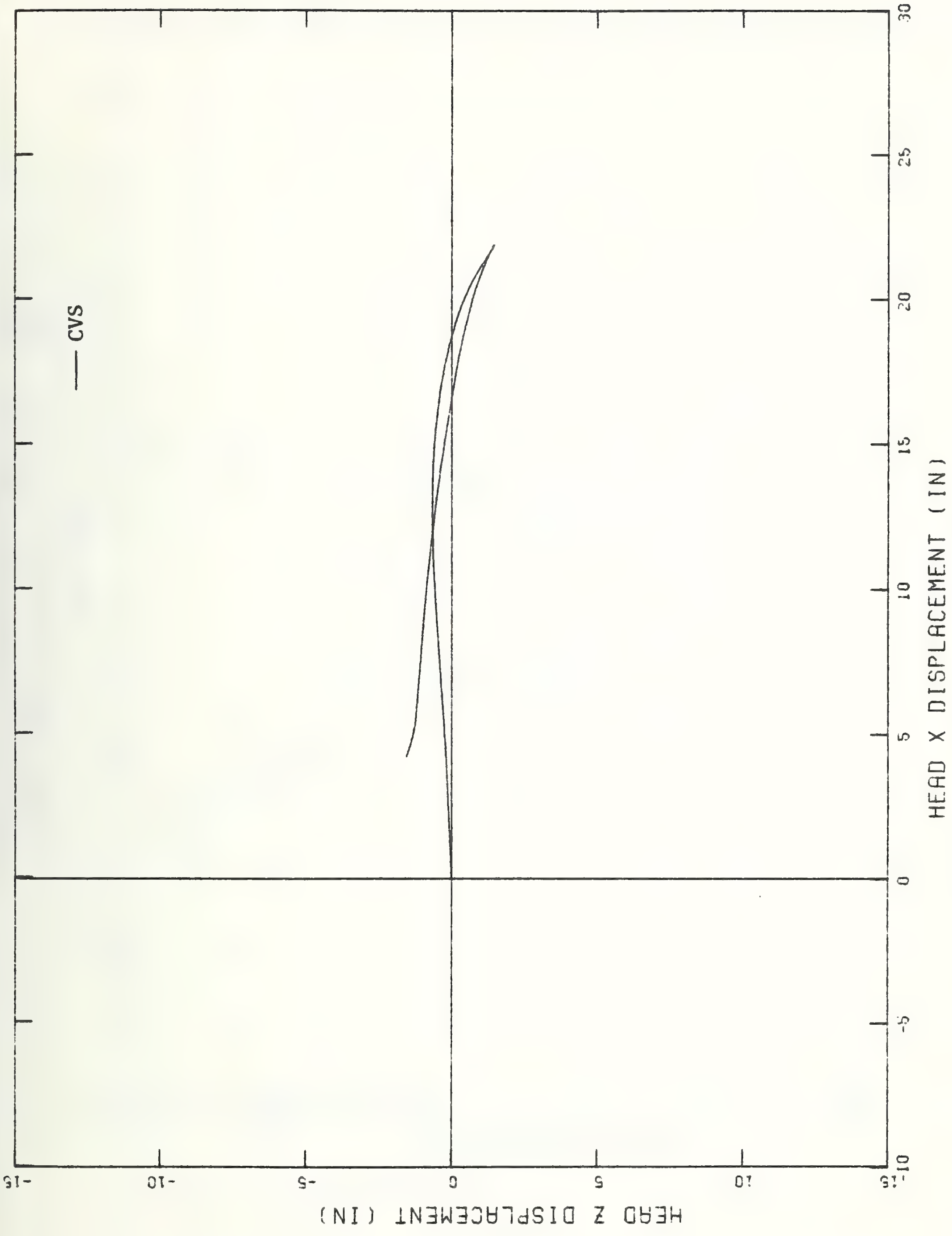
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2219 (R2219B)



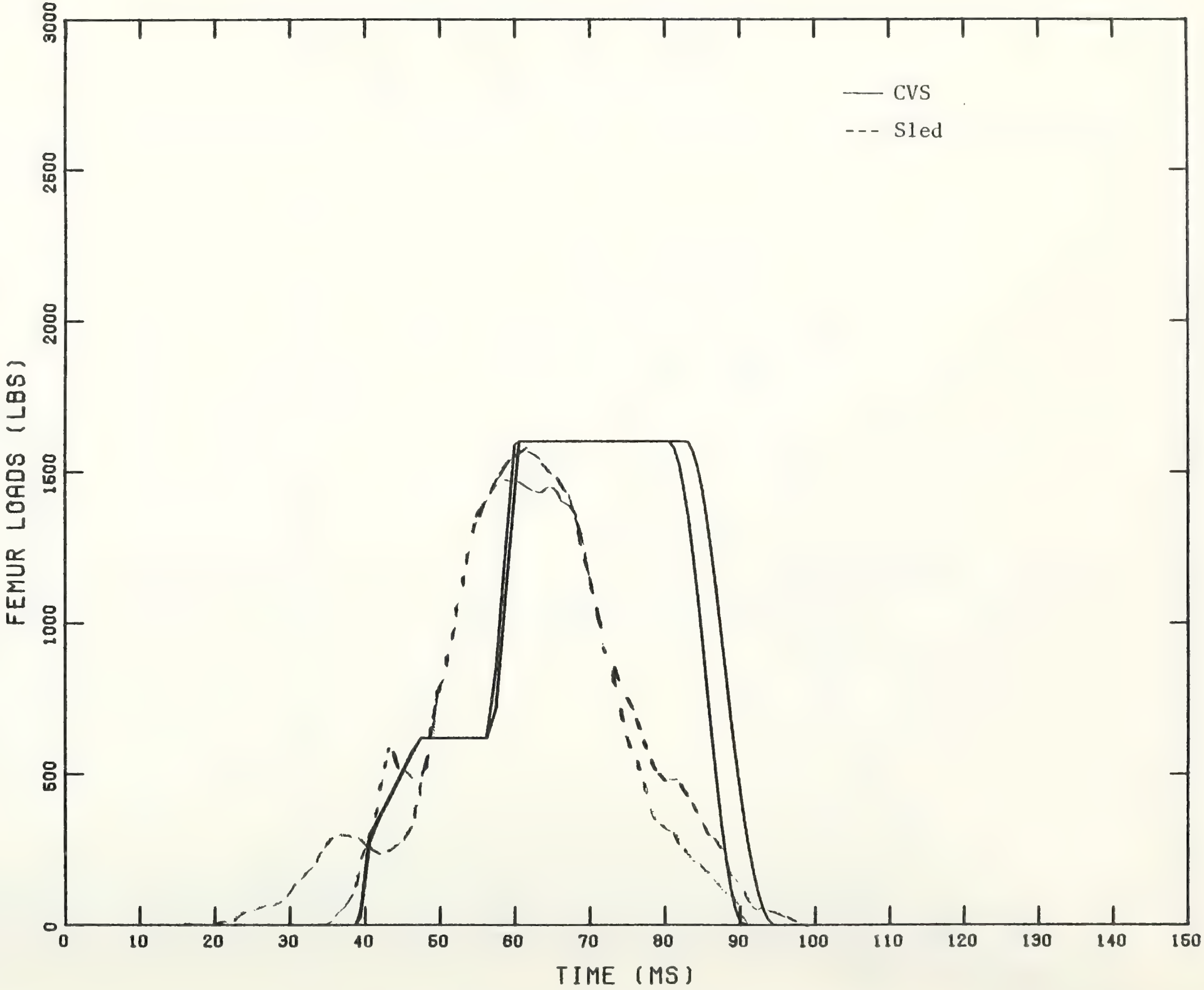
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2119 (R2119B - TASK 4)



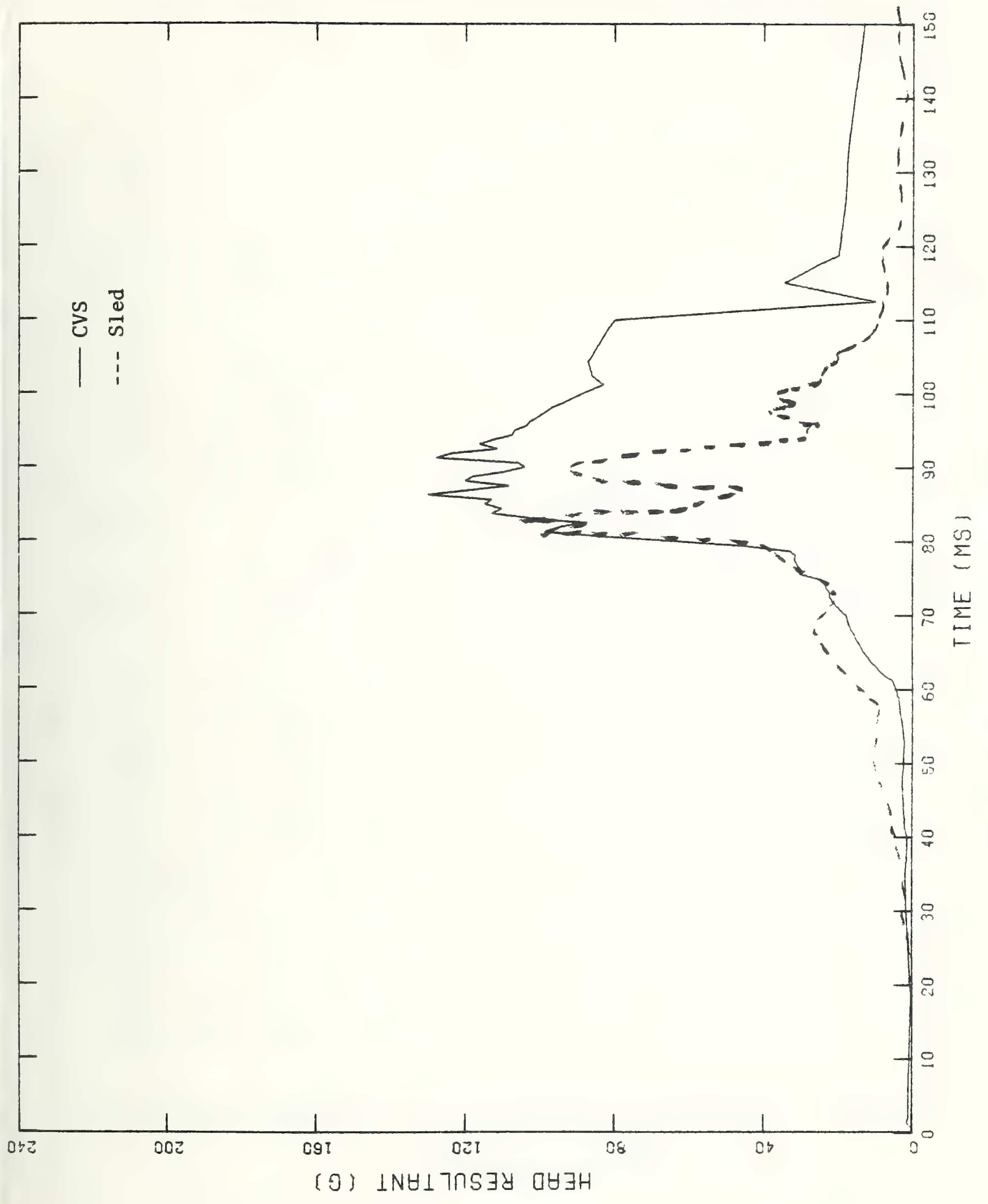
BELT LOADS VS. TIME
SIMULATION OF RUN 2119 (R2119A - TASK 4)



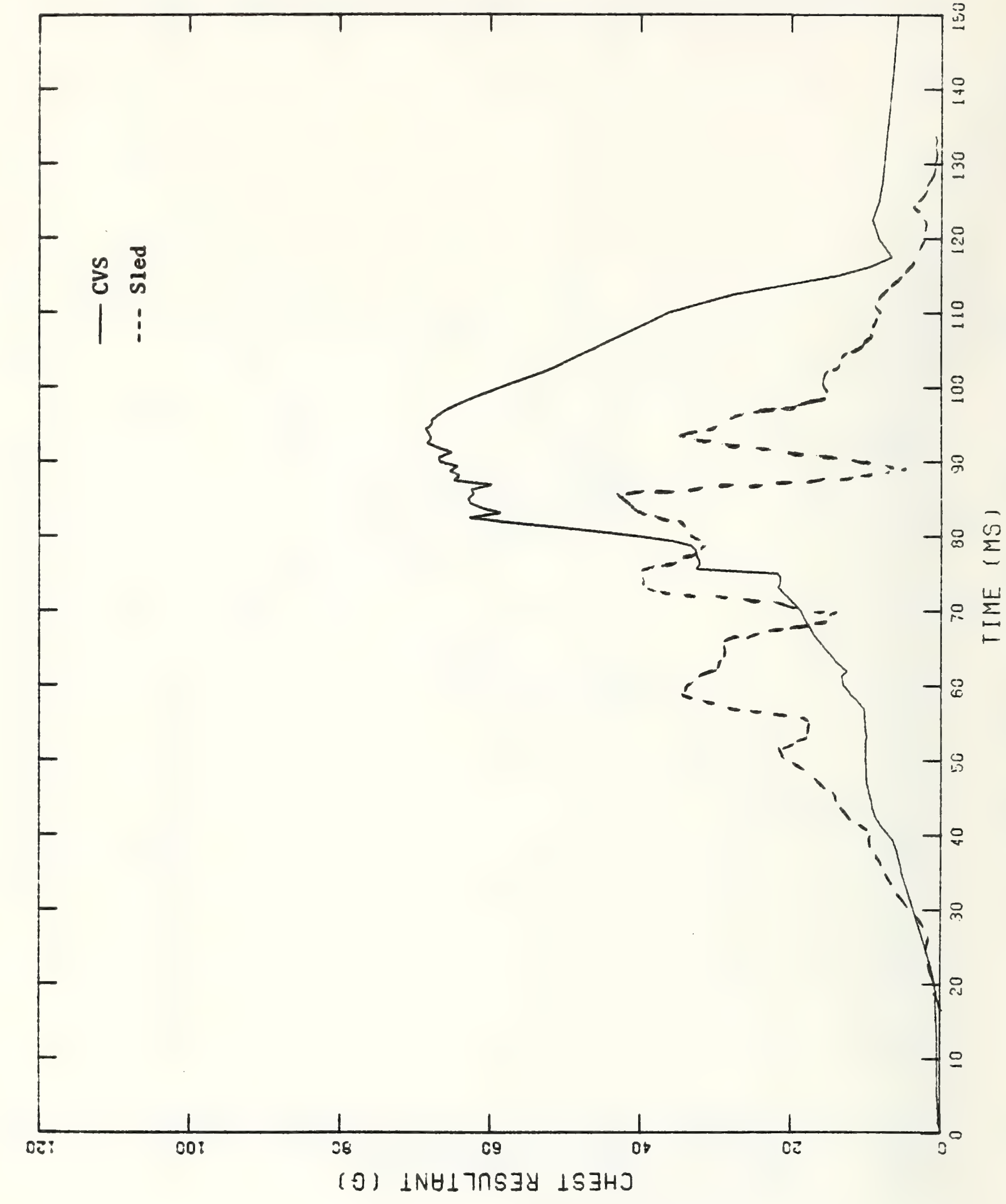
HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2119 (R2119B)



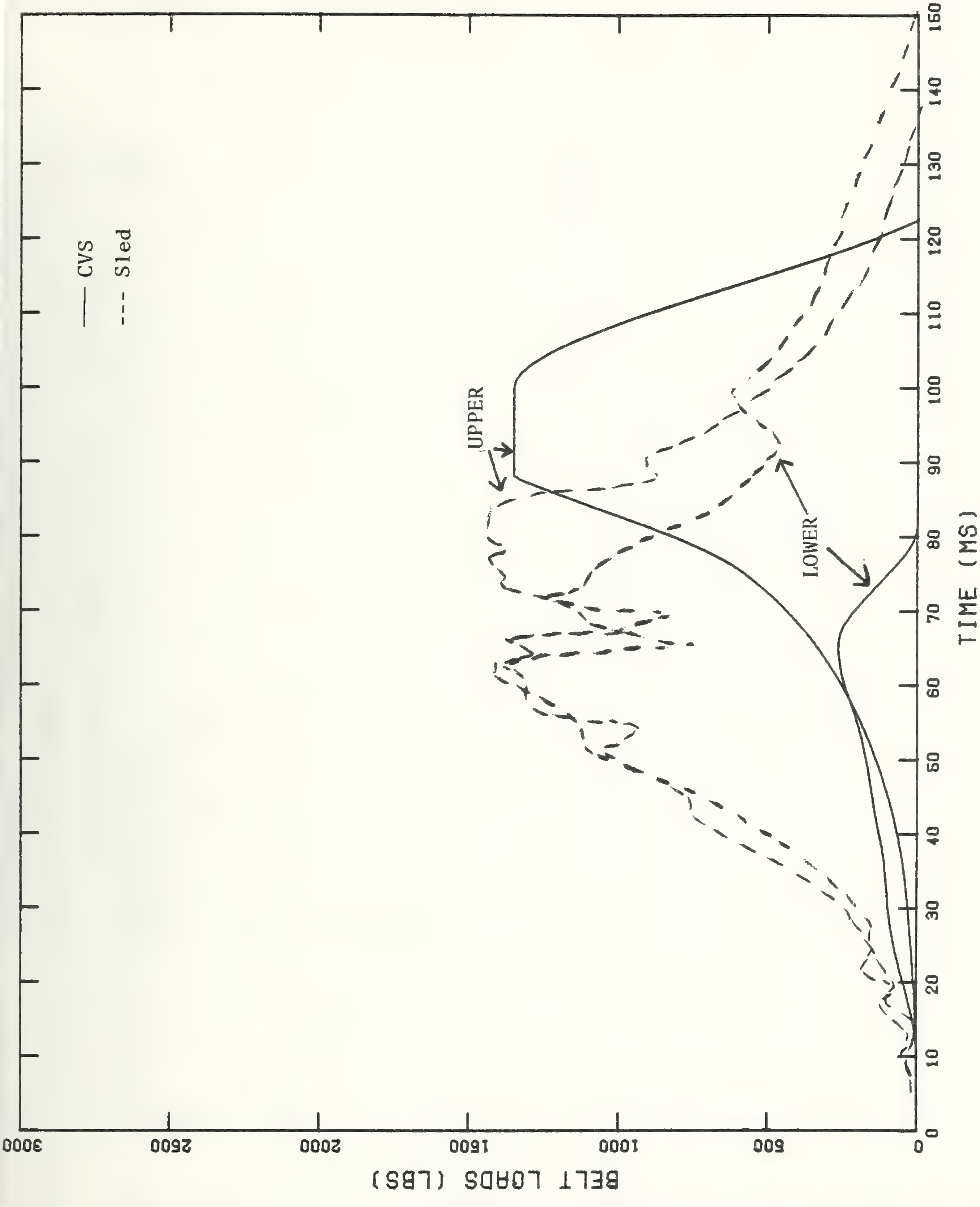
RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2119 (R2119A - TASK 4)



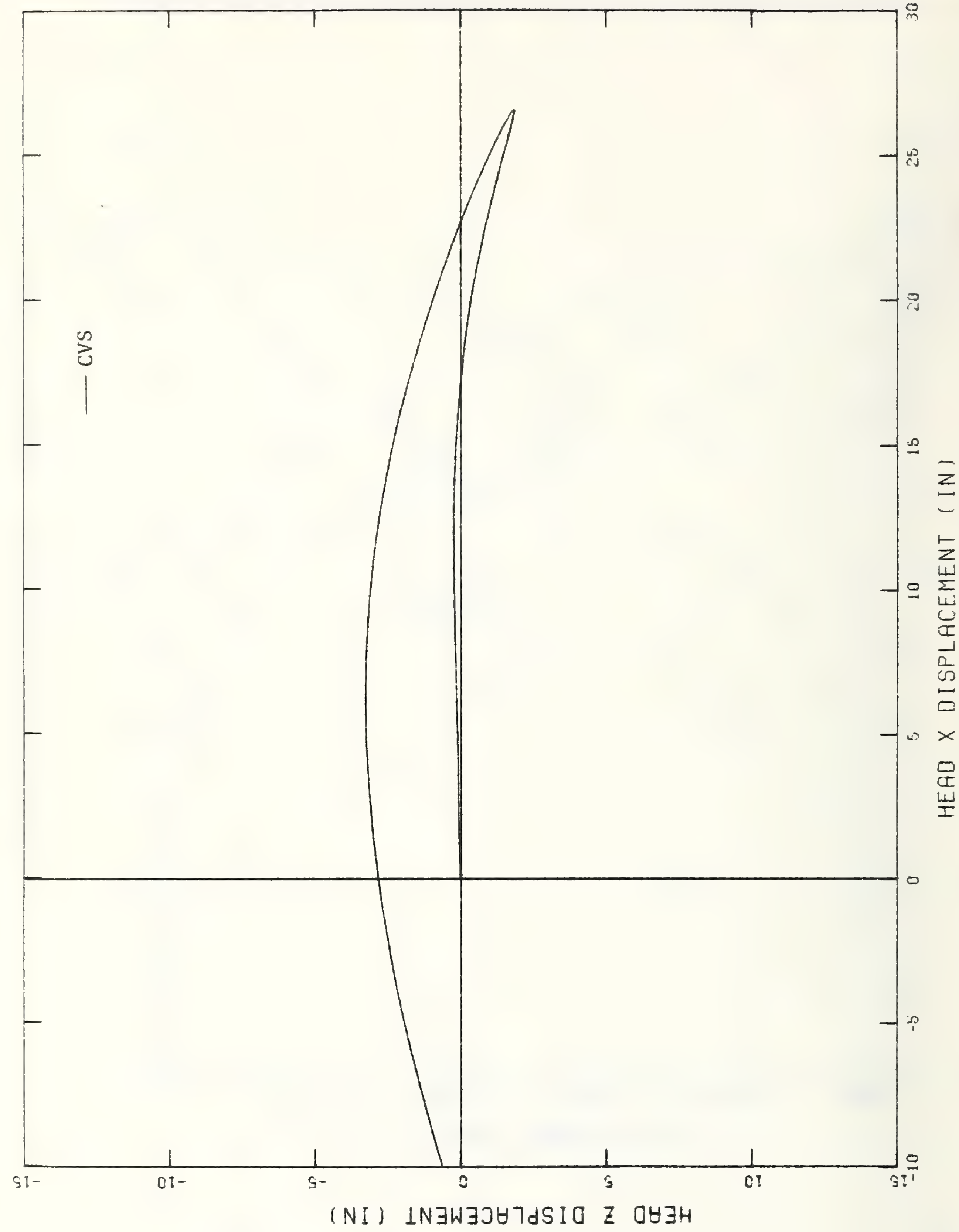
HEAD RESULTANT ACCELERATION VS TIME
SIMULATION OF RUN 2118 (R2118B - TASK 4)



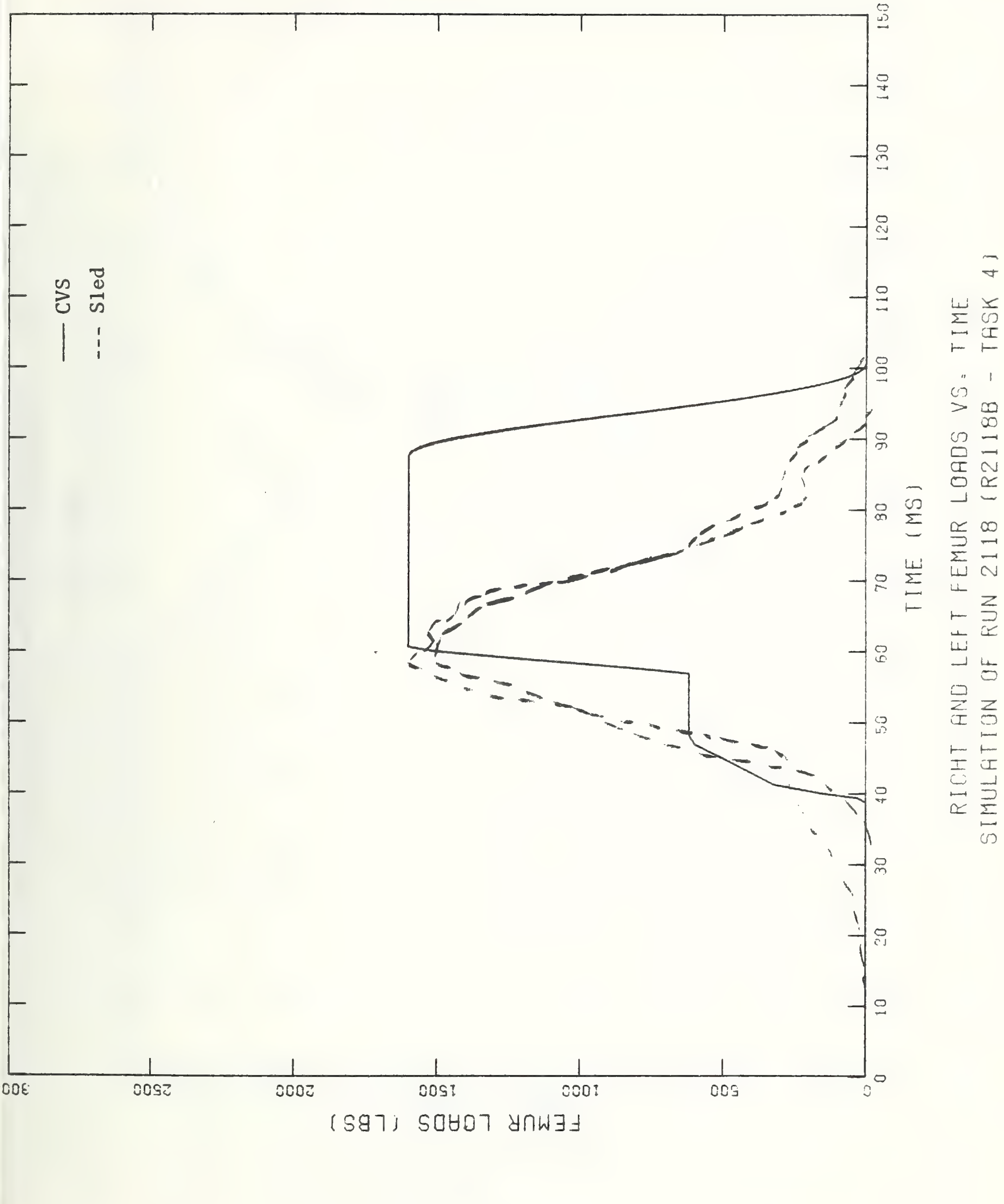
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2118 (R2118B - TASK 4)

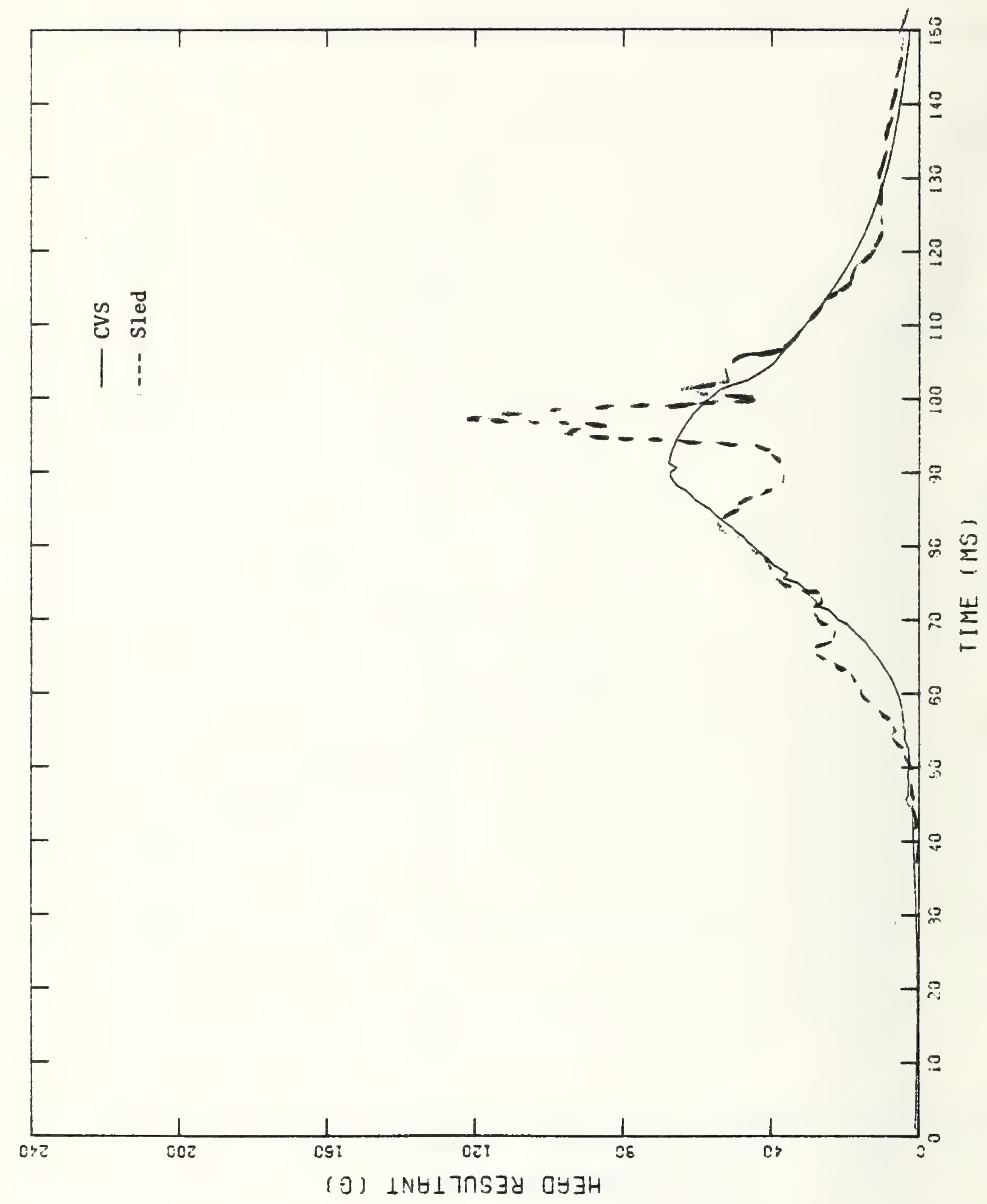


BELT LOADS VS. TIME
SIMULATION OF RUN 2118 (R2118B - TASK 4)

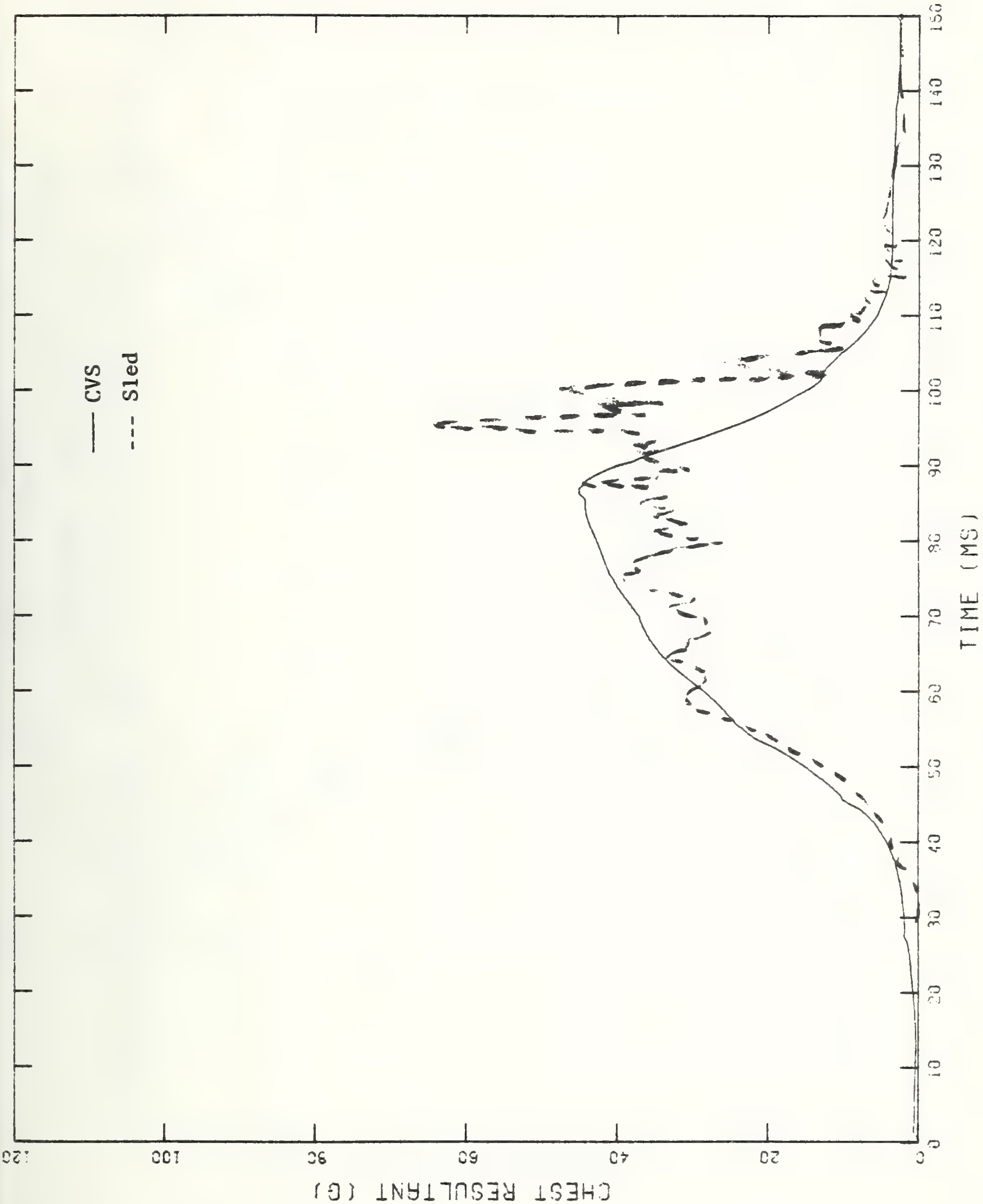


HEAD X VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2118 (R2118B - TASK 4)

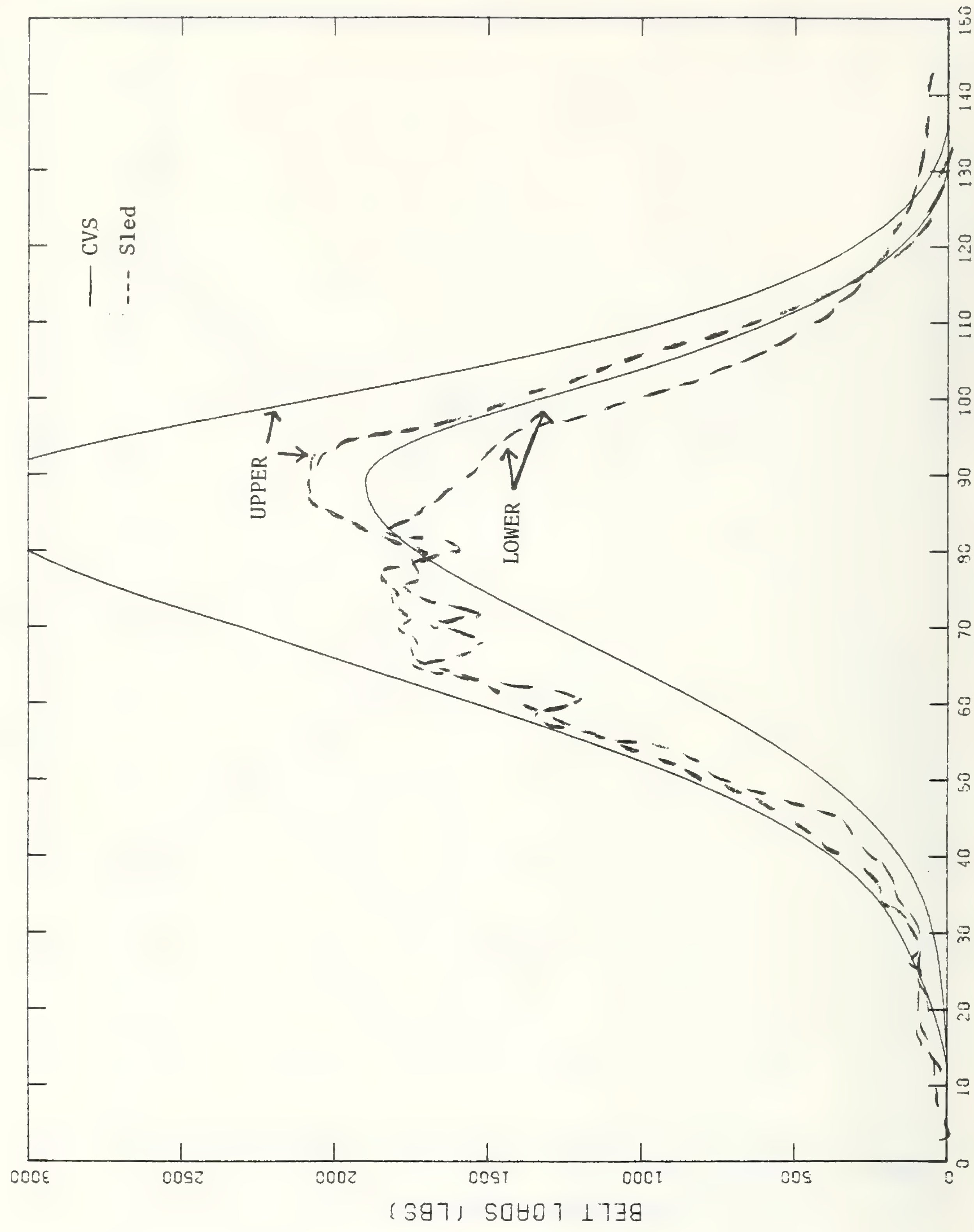

RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2118 (R2118B - TASK 4)
TIME (MS)
FEMUR LOADS (LBS)
CVS
Sled
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
500
1000
1500
2000
2500
3000



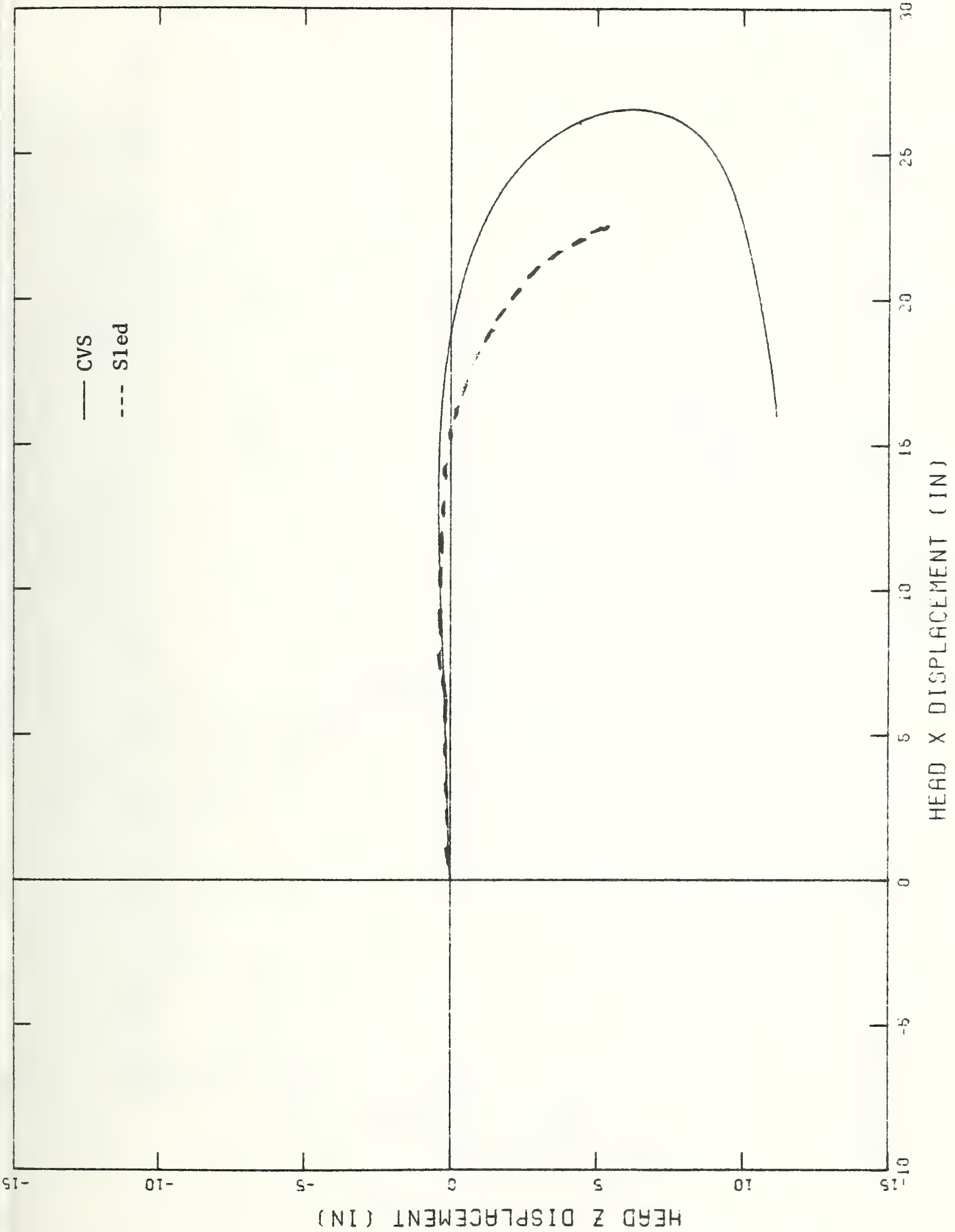
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2028A



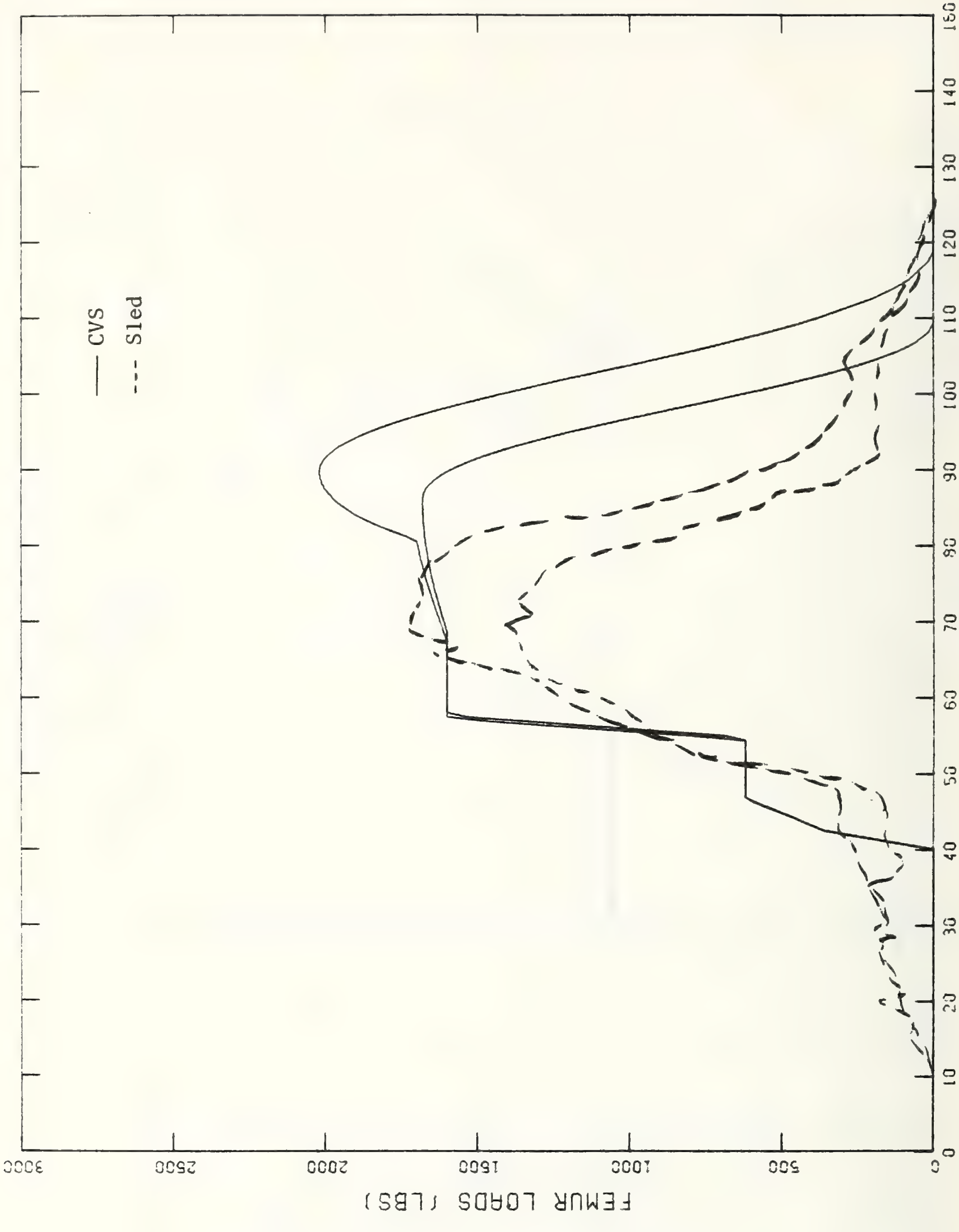
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2028A



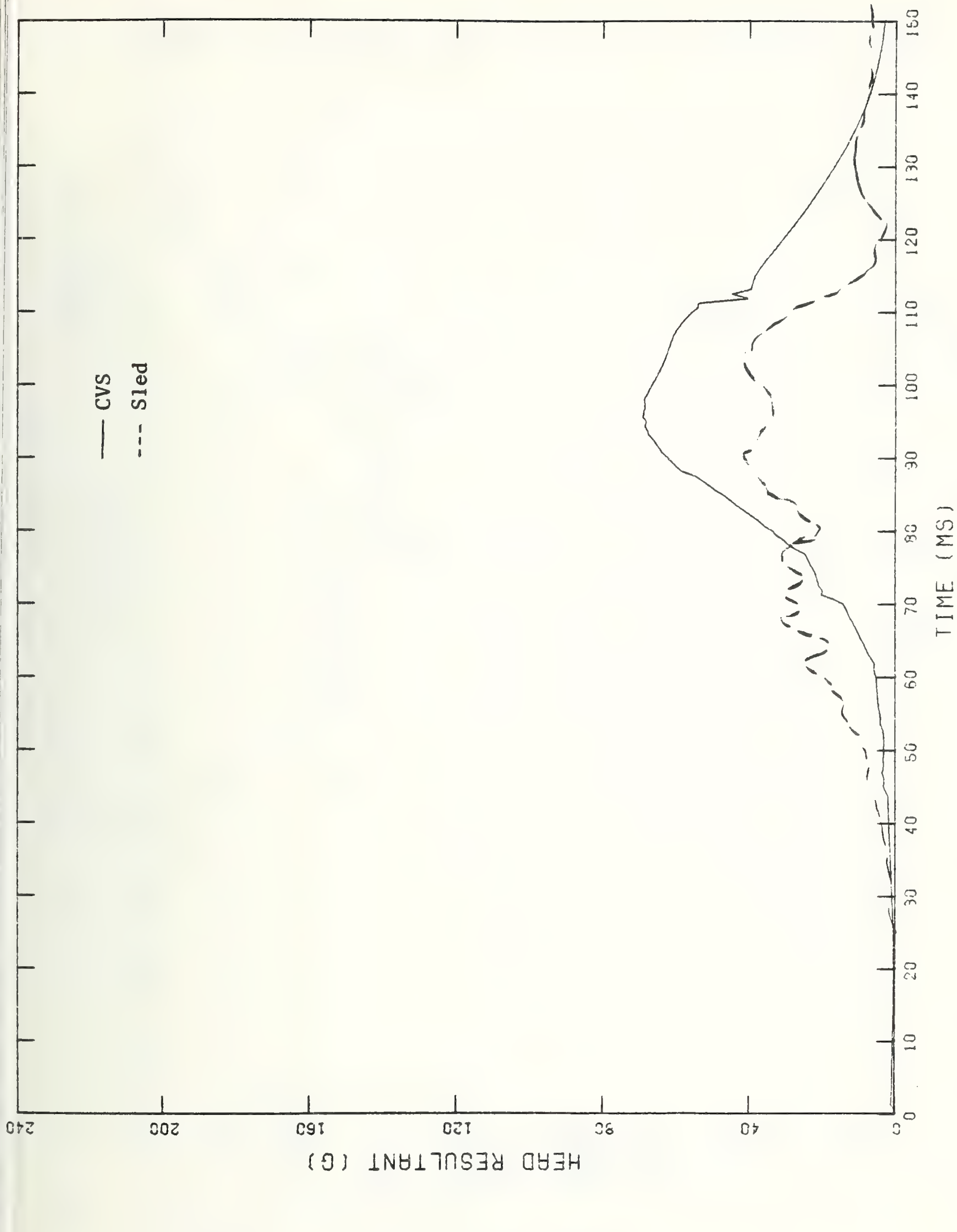
BELT LOADS VS. TIME
SIMULATION OF RUN 2028A



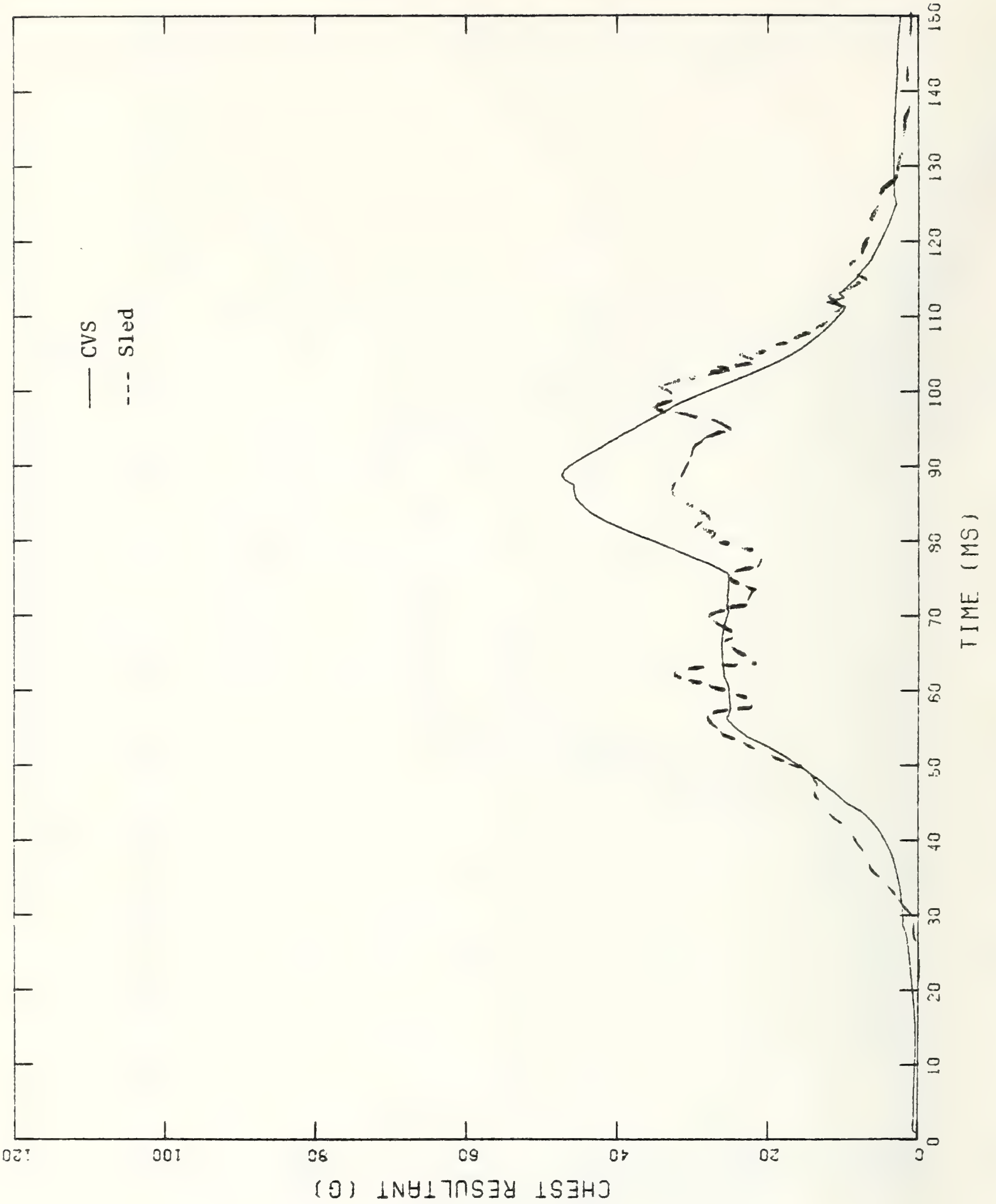
HEAD Z VS. HEAD X DISPLACEMENT
SIMULATION OF RUN 2028A



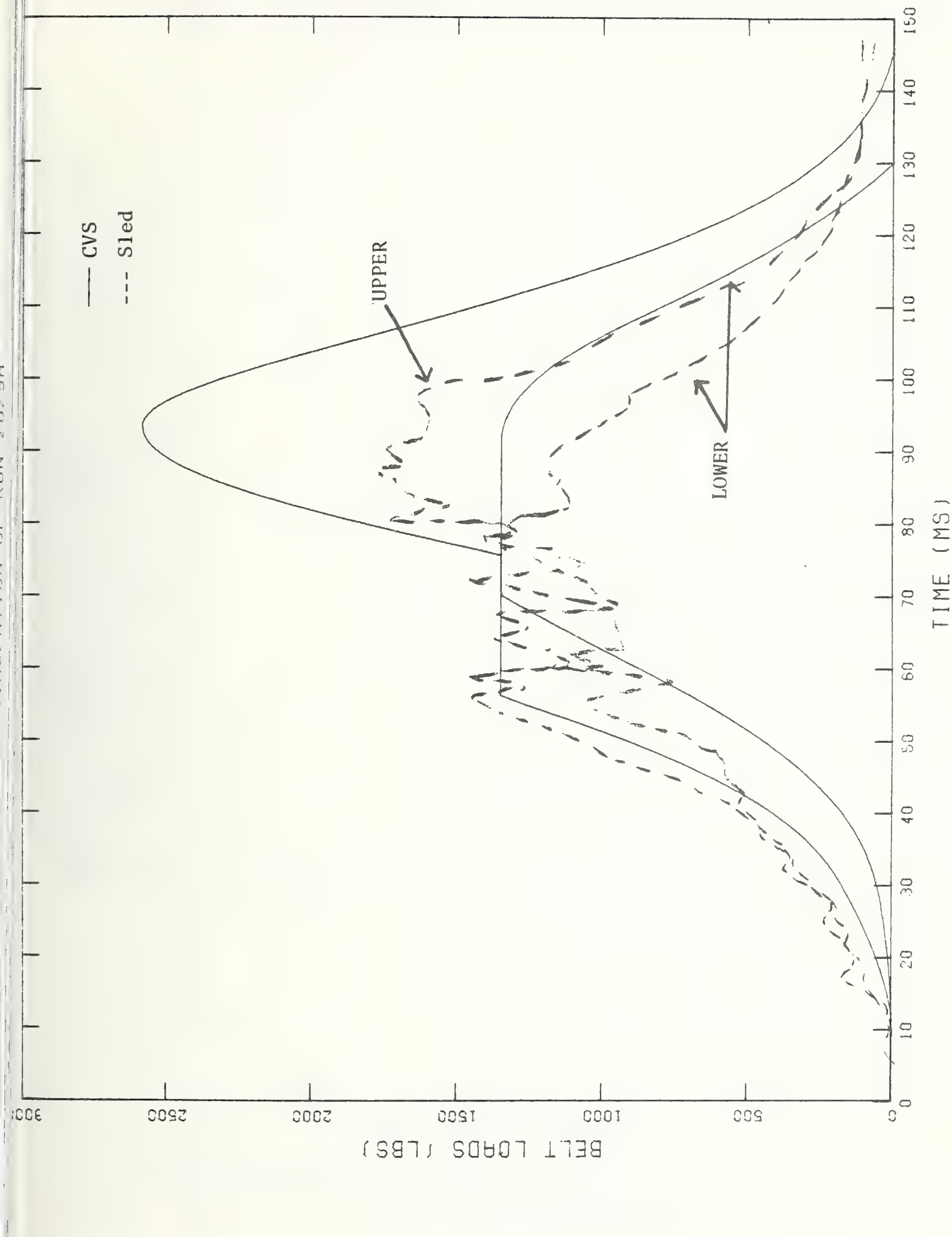
RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2028A



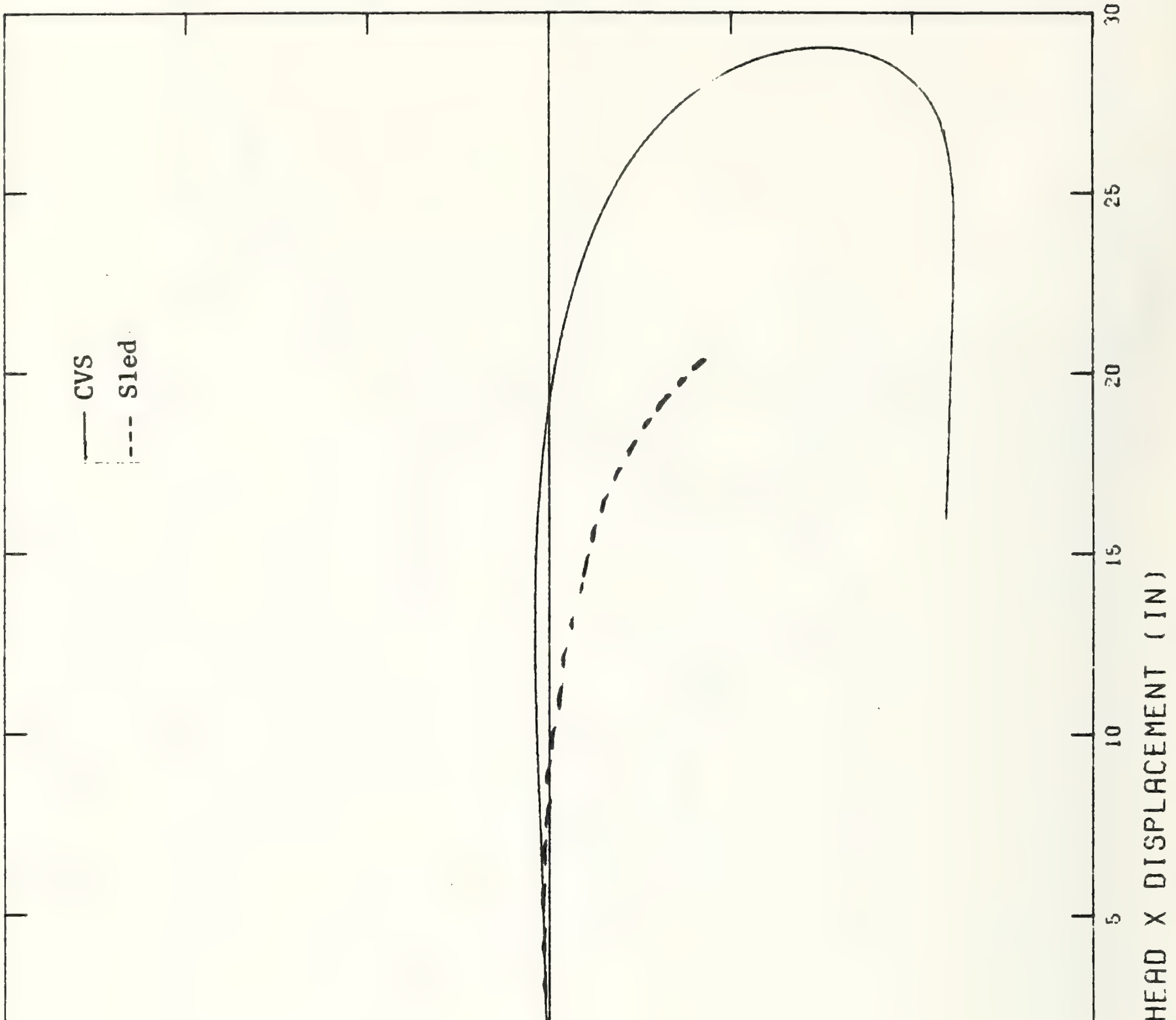
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2029A



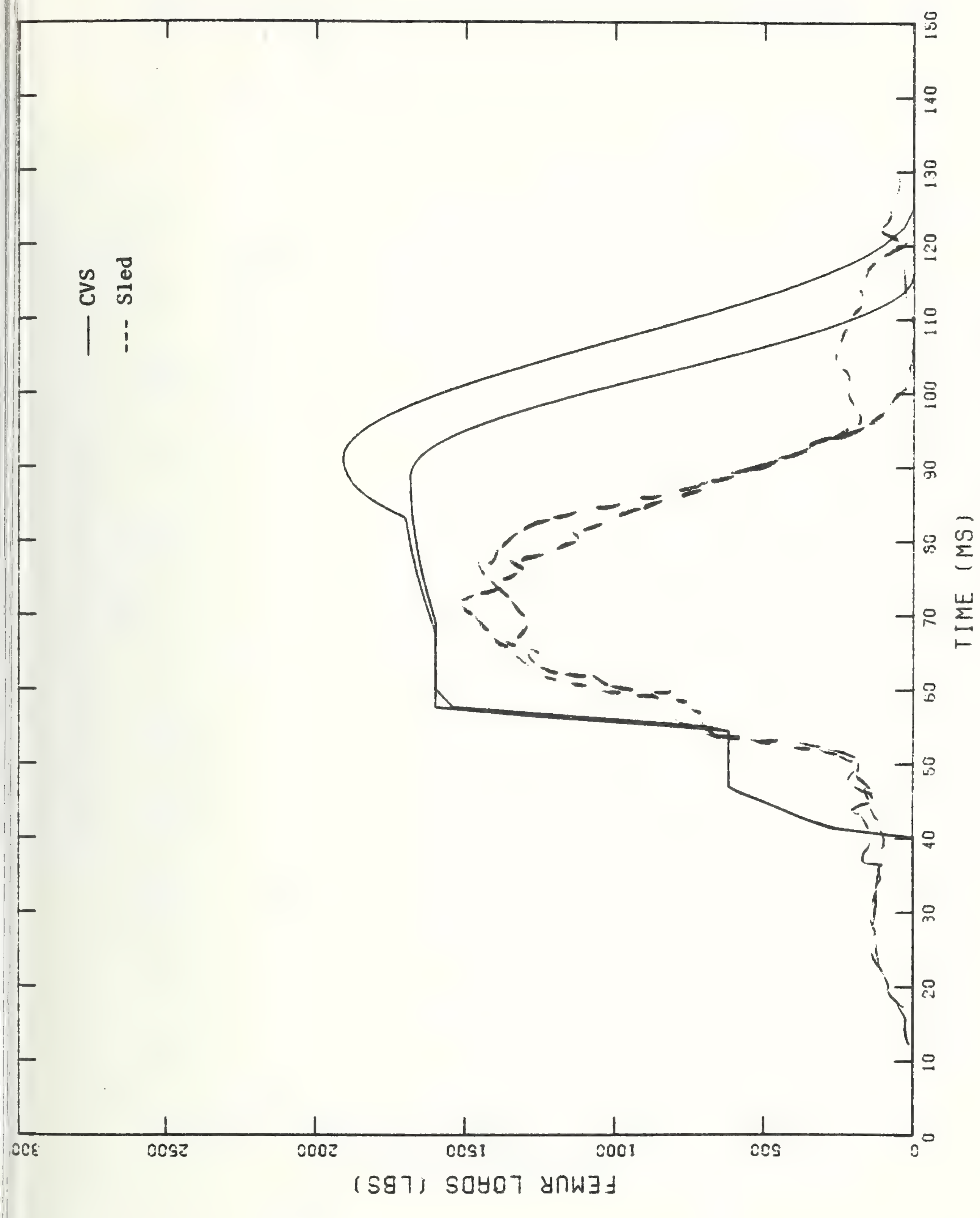
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2029A



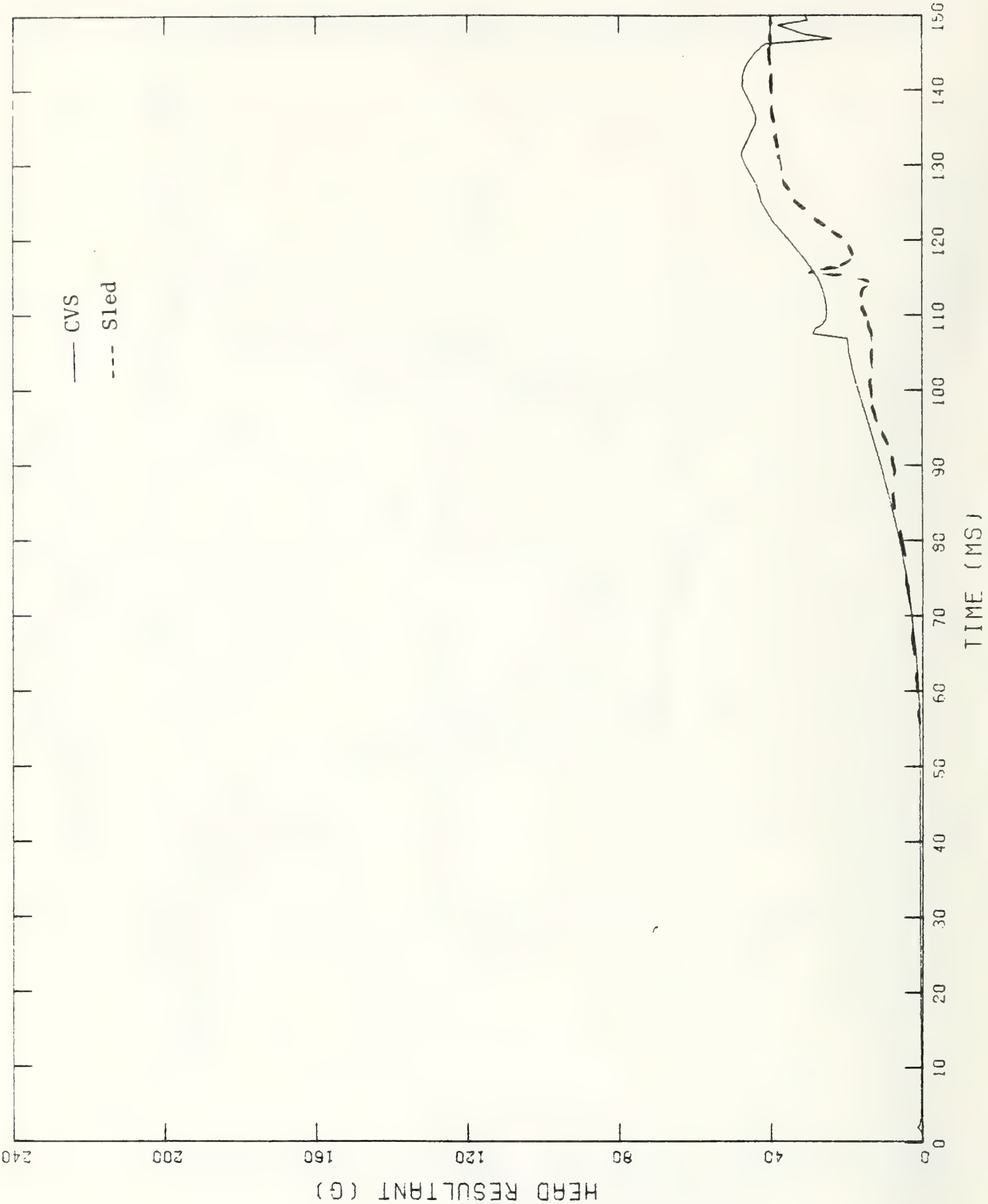
BELT LOADS VS. TIME
SIMULATION OF RUN 2029A



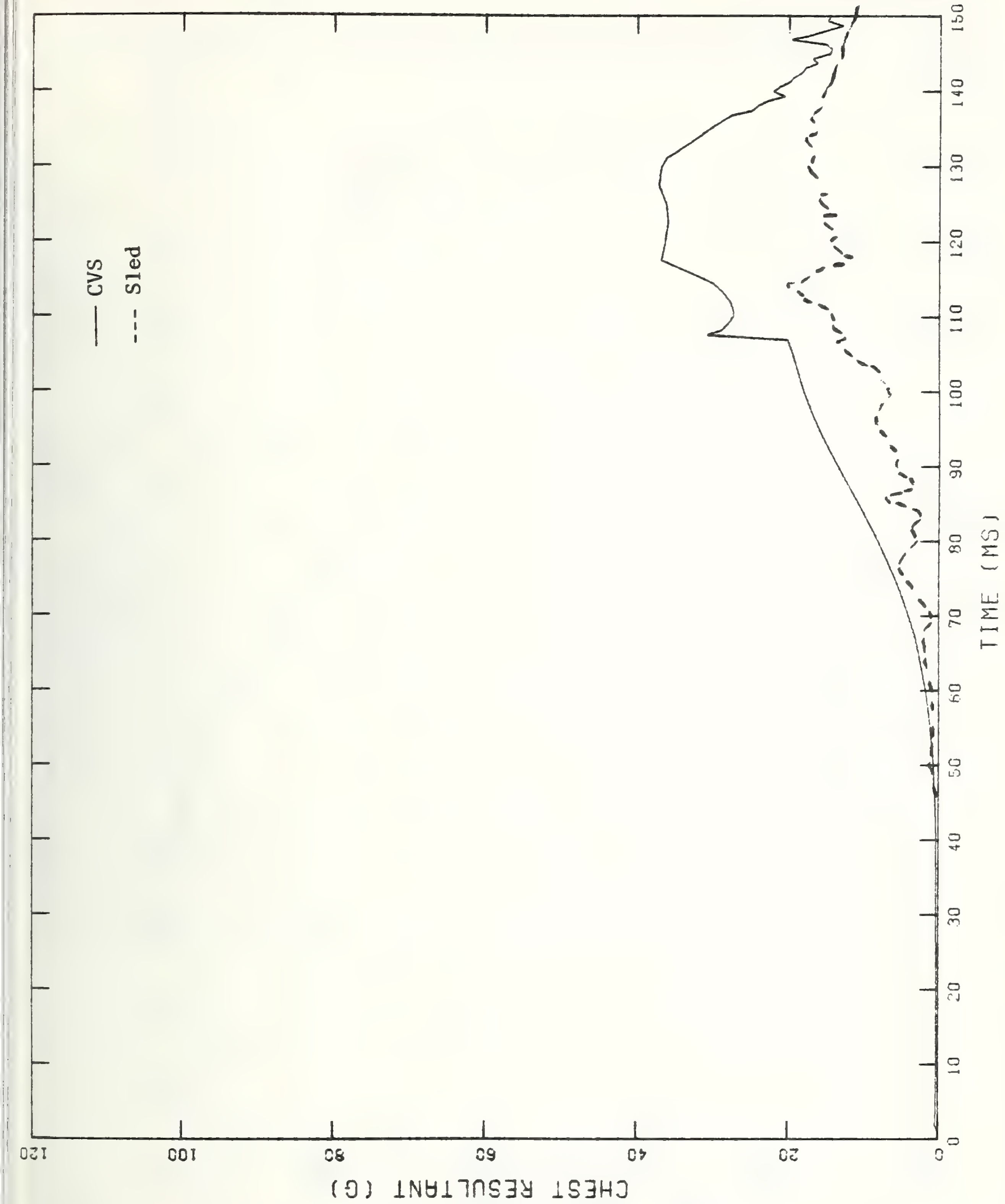
HEAD Z VS. HEAD X DISPLACEMENT
SIMULATION OF RUN 2029A



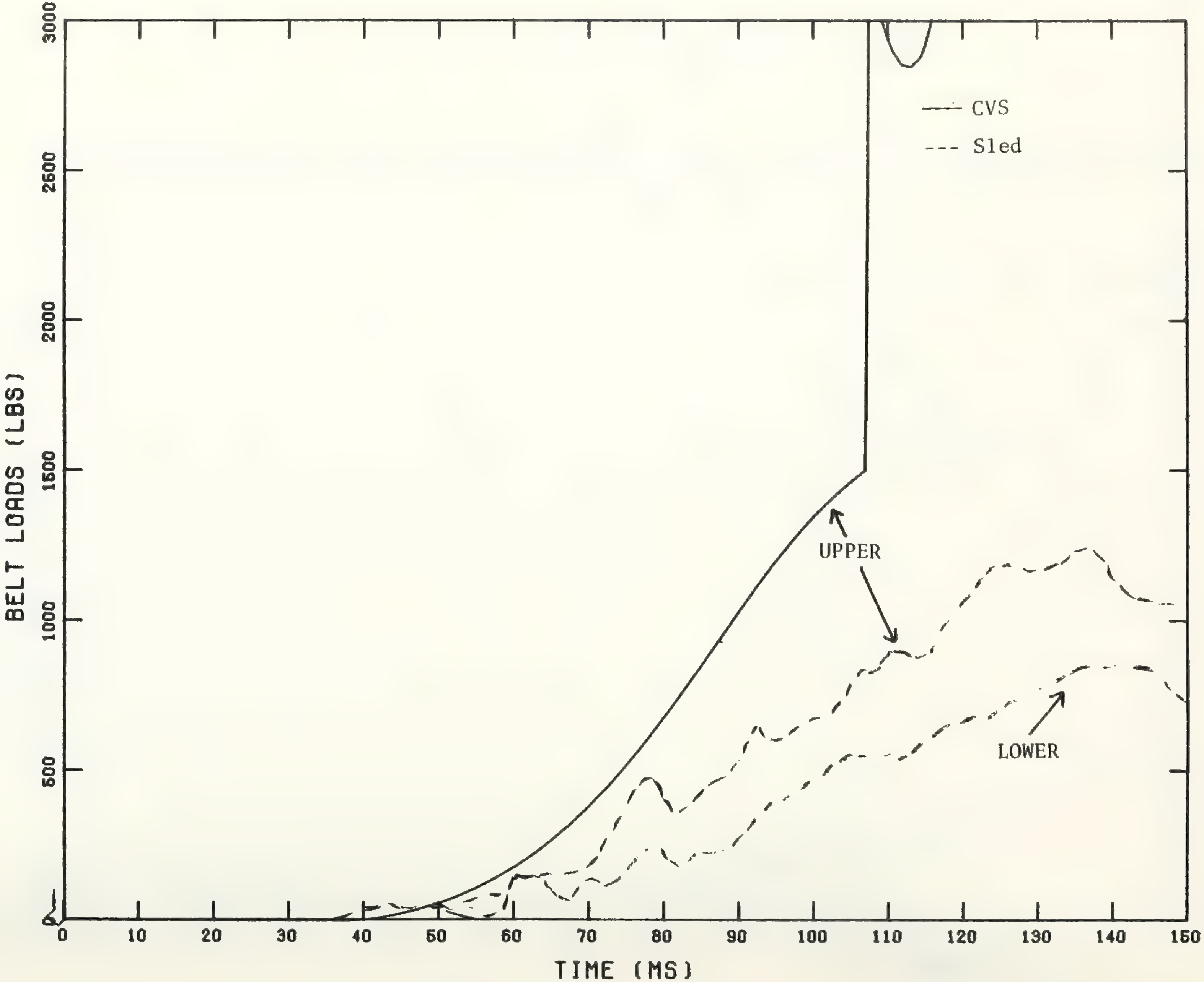
RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF RUN 2029A



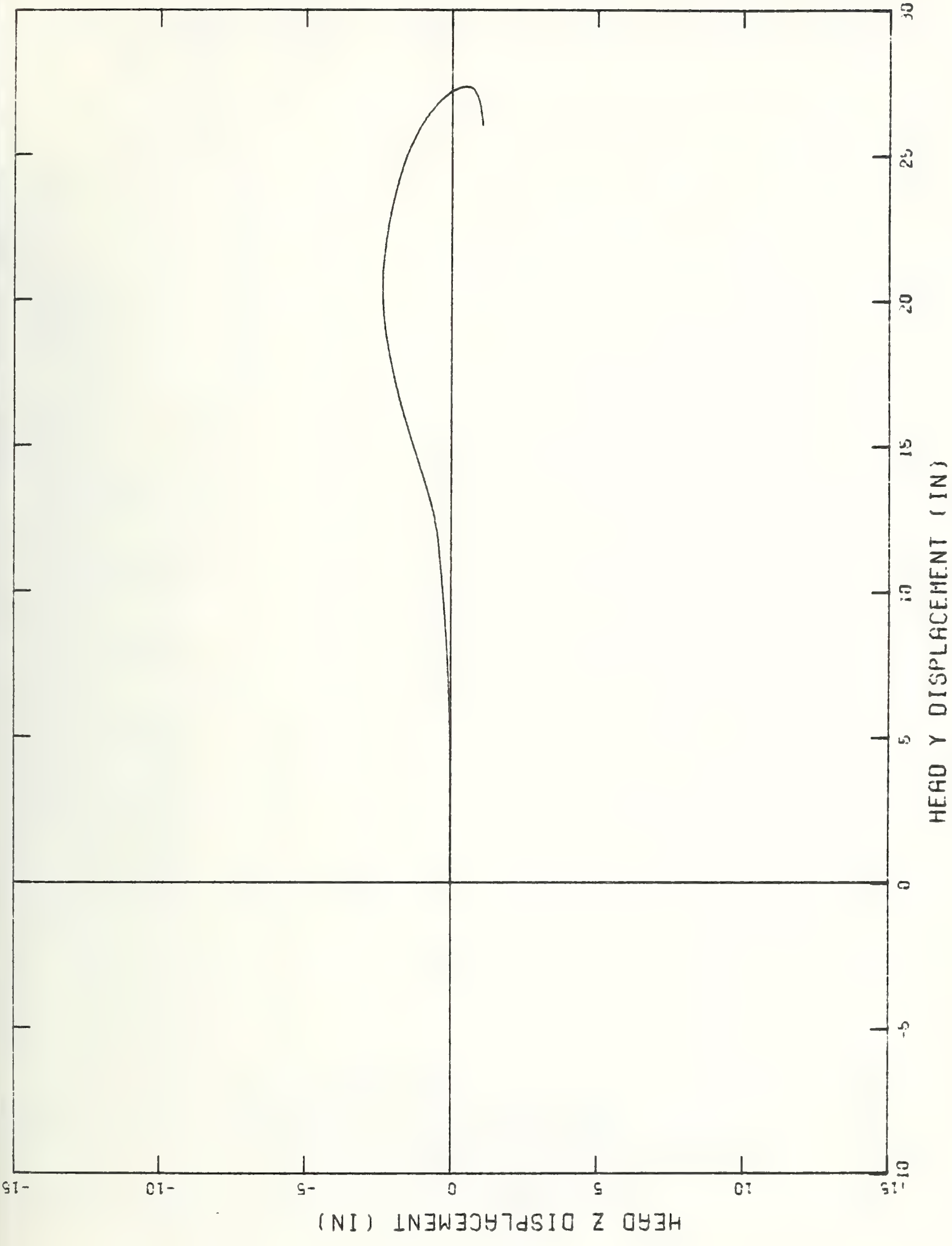
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2208 (R2208B - TASK 4)



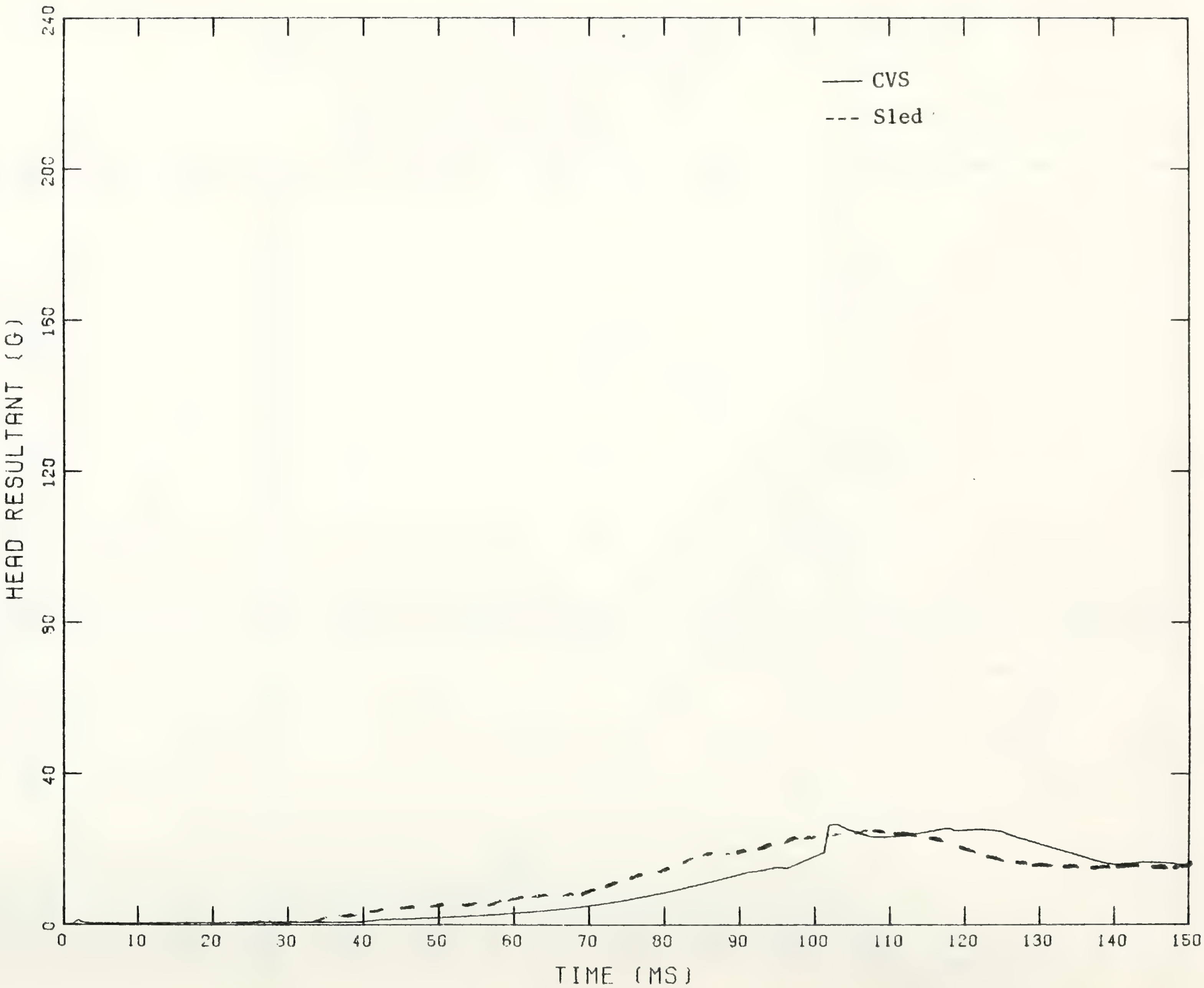
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2208 (R2208B - TASK 4)



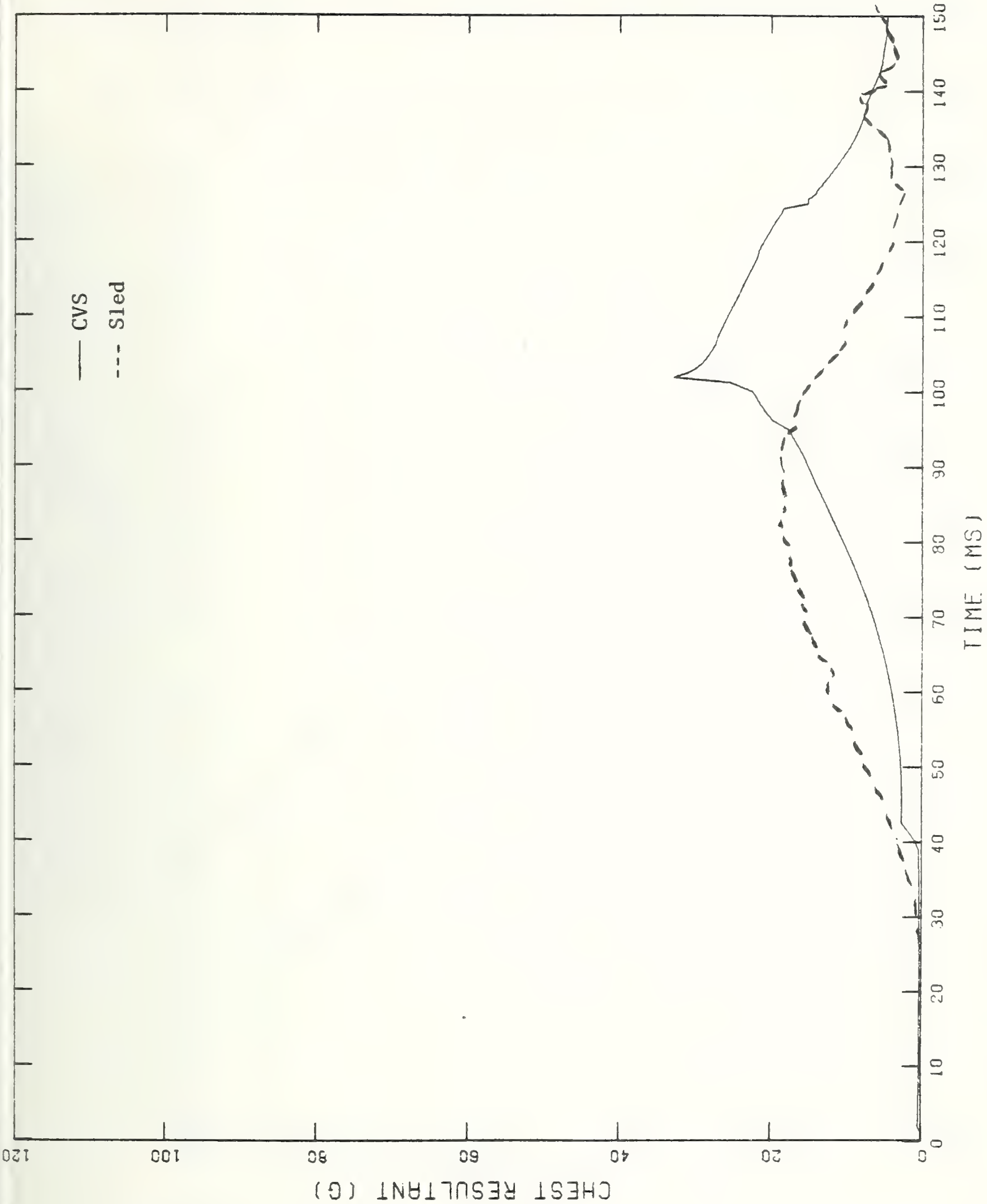
BELT LOADS VS. TIME
SIMULATION OF RUN 2208 (R2208B - TASK 4)



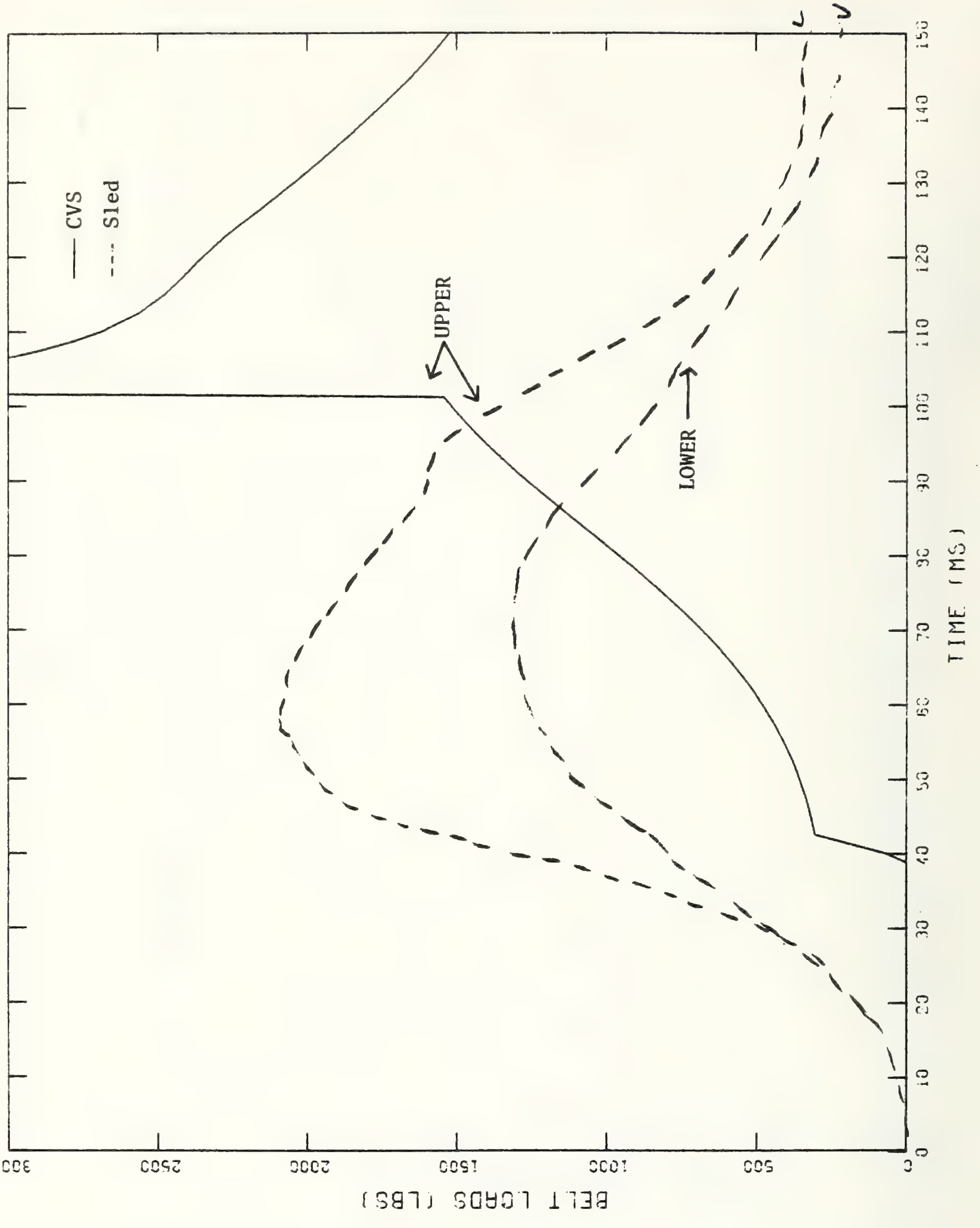
HEAD Y VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2208 (R2208A - TASK 4)



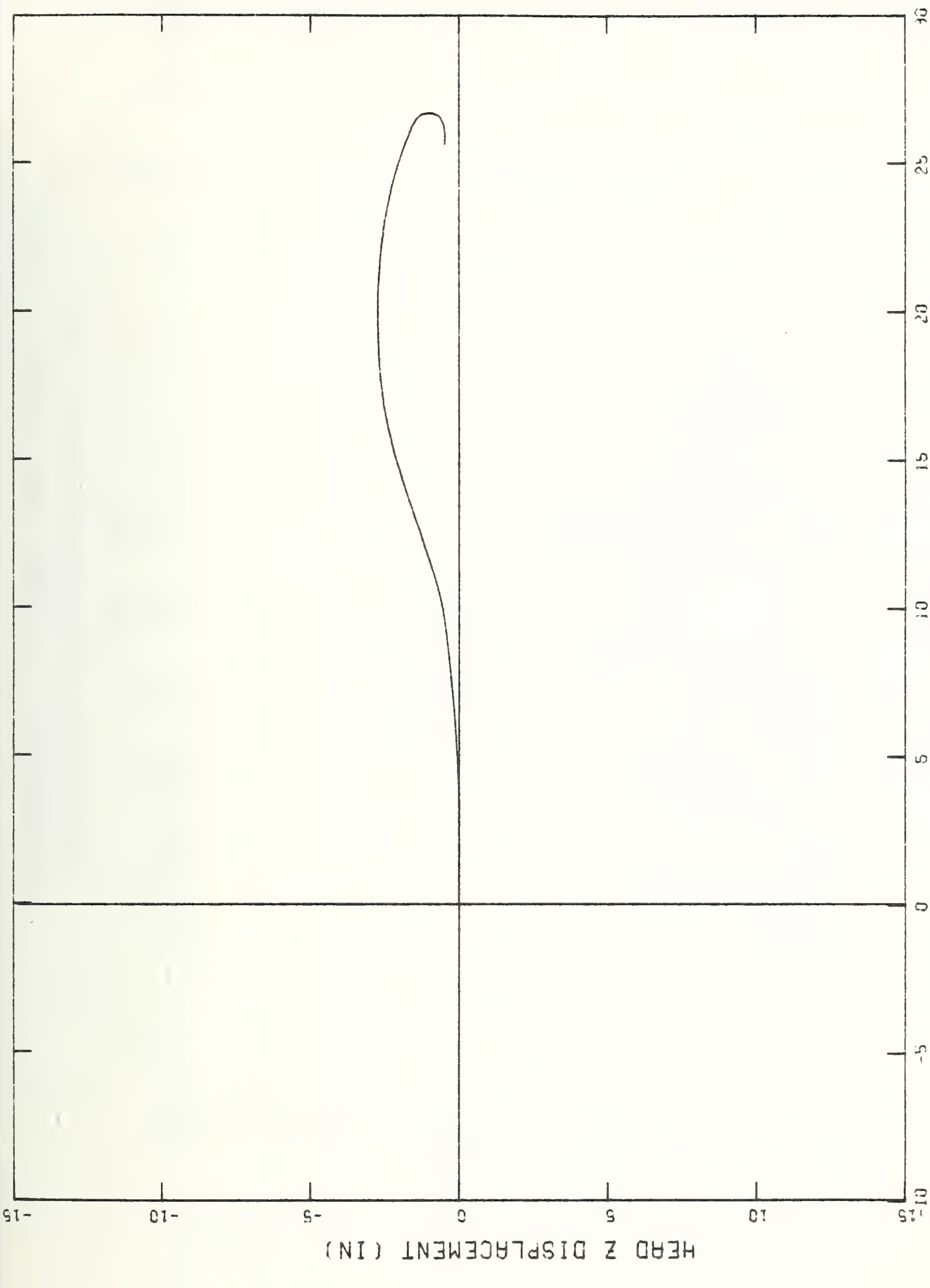
HEAD RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2209 (R2209B - TASK 4)



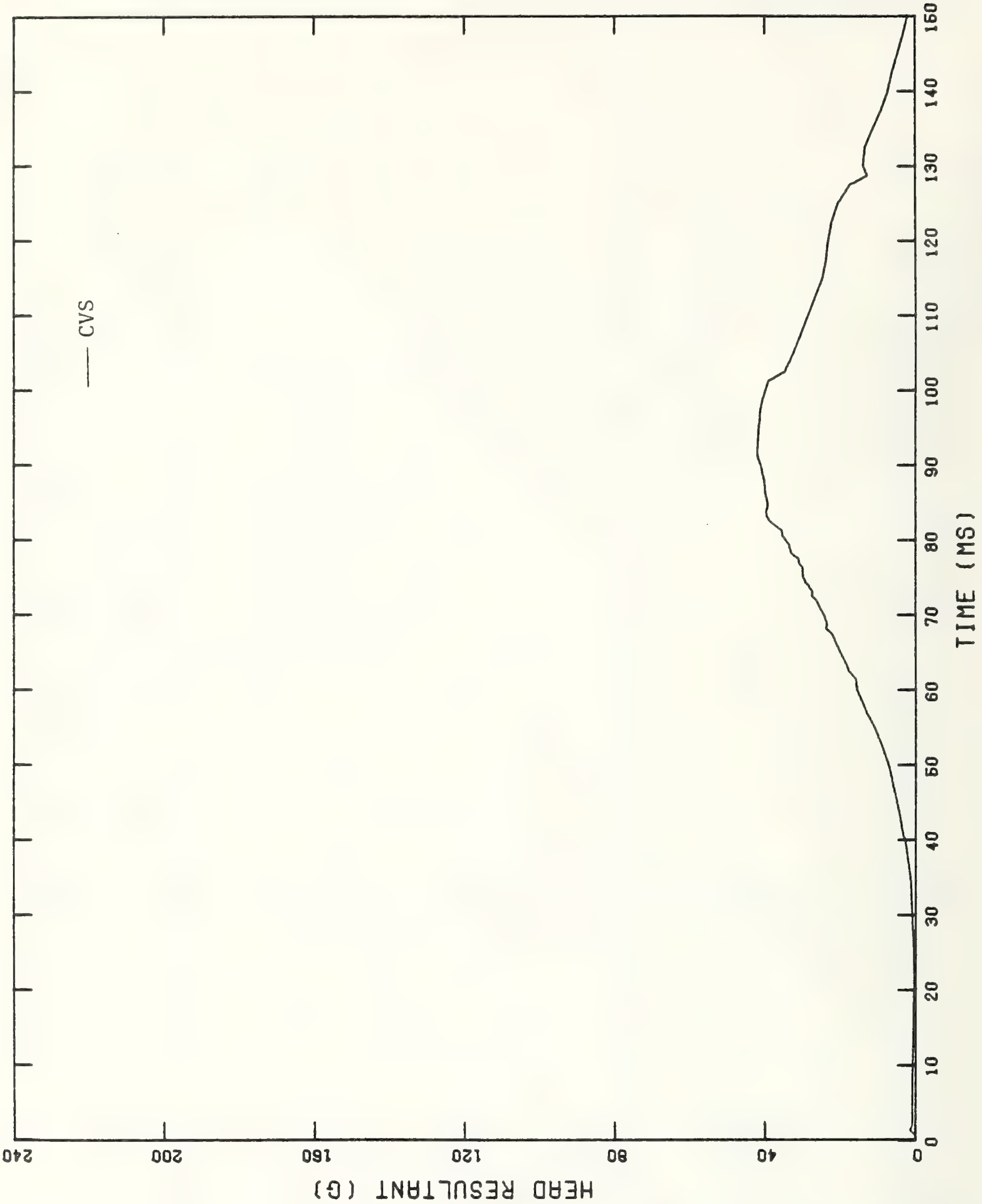
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF RUN 2209 (R2209B - TASK 4)



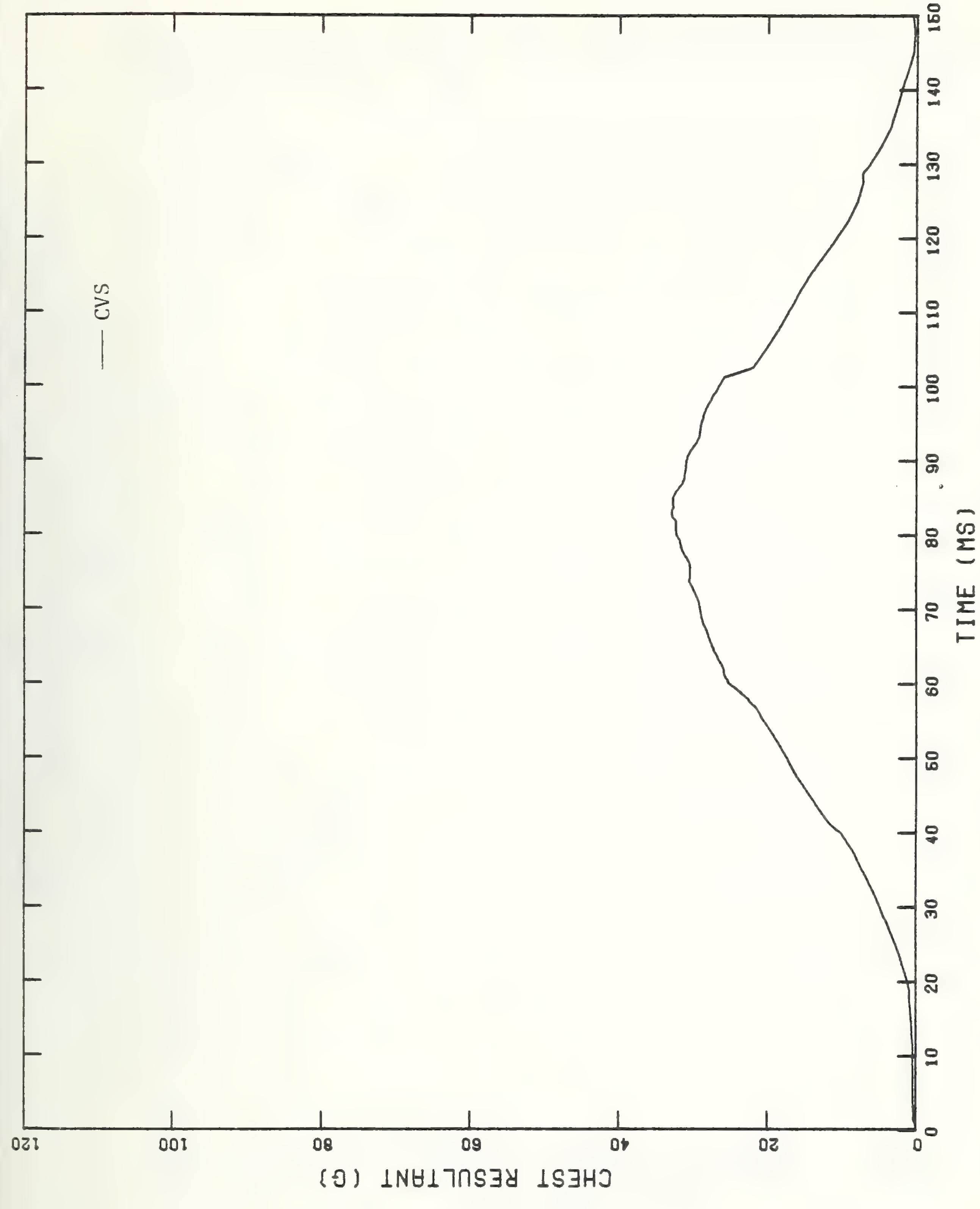
BELT LOADS VS. TIME
SIMULATION OF RUN 2209 (R2209B - TASK 4



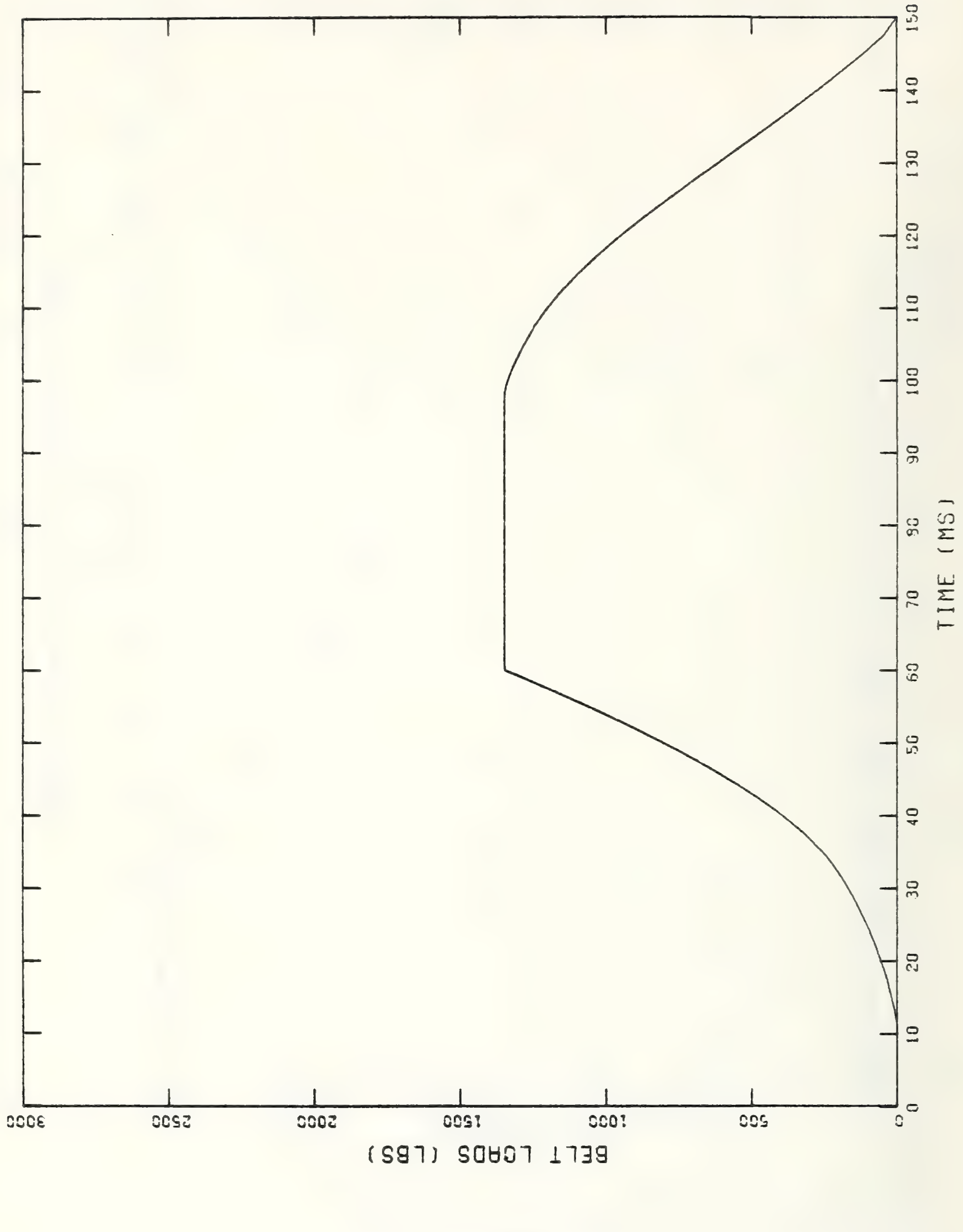
HEAD Y VS. HEAD Z DISPLACEMENT
SIMULATION OF RUN 2209 (R2209A - TASK 4)



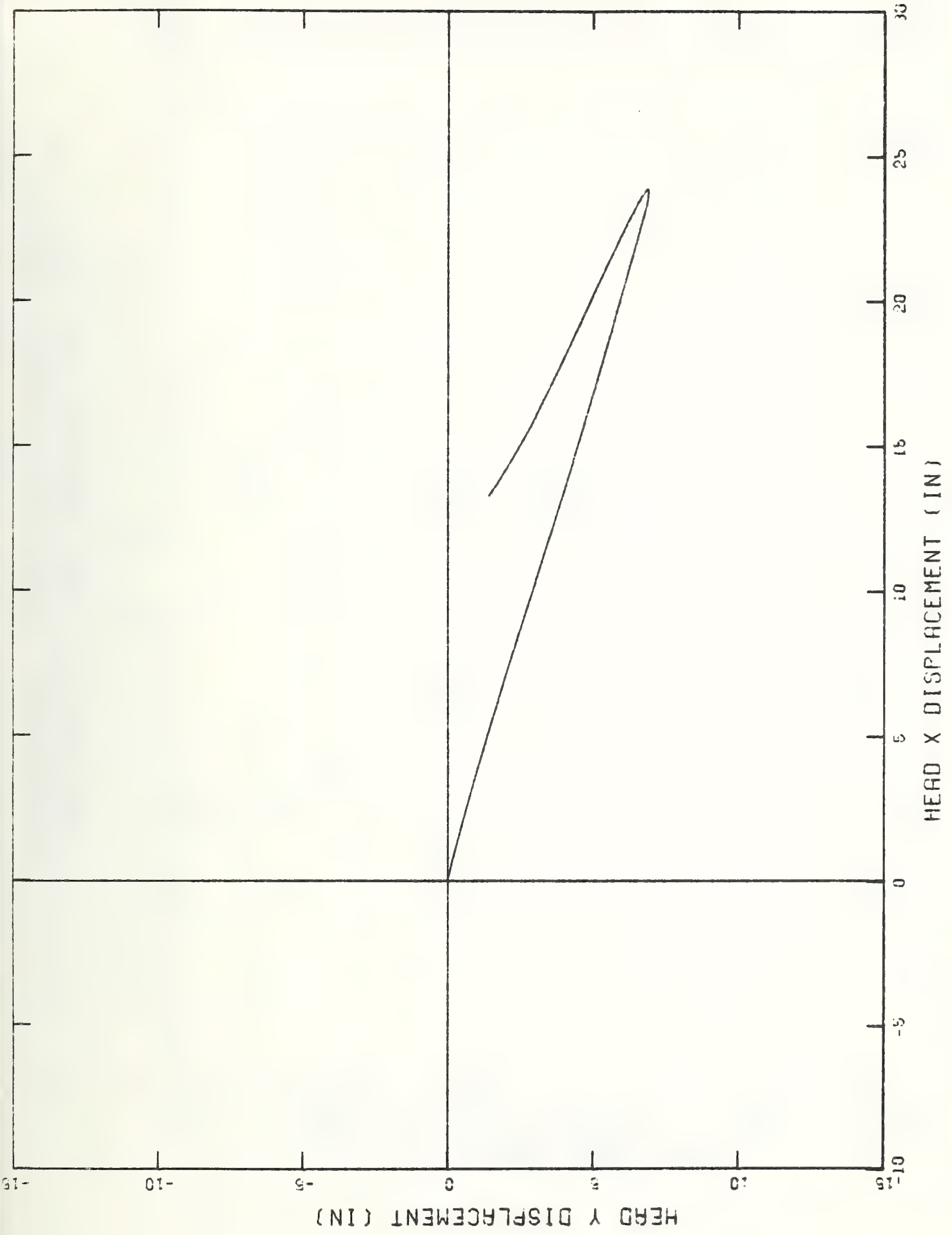
HEAD RESULTANT ACCELERATION VS.TIME
SIMULATION OF 14 DEGREE RUN (R14DEG - TASK 4)



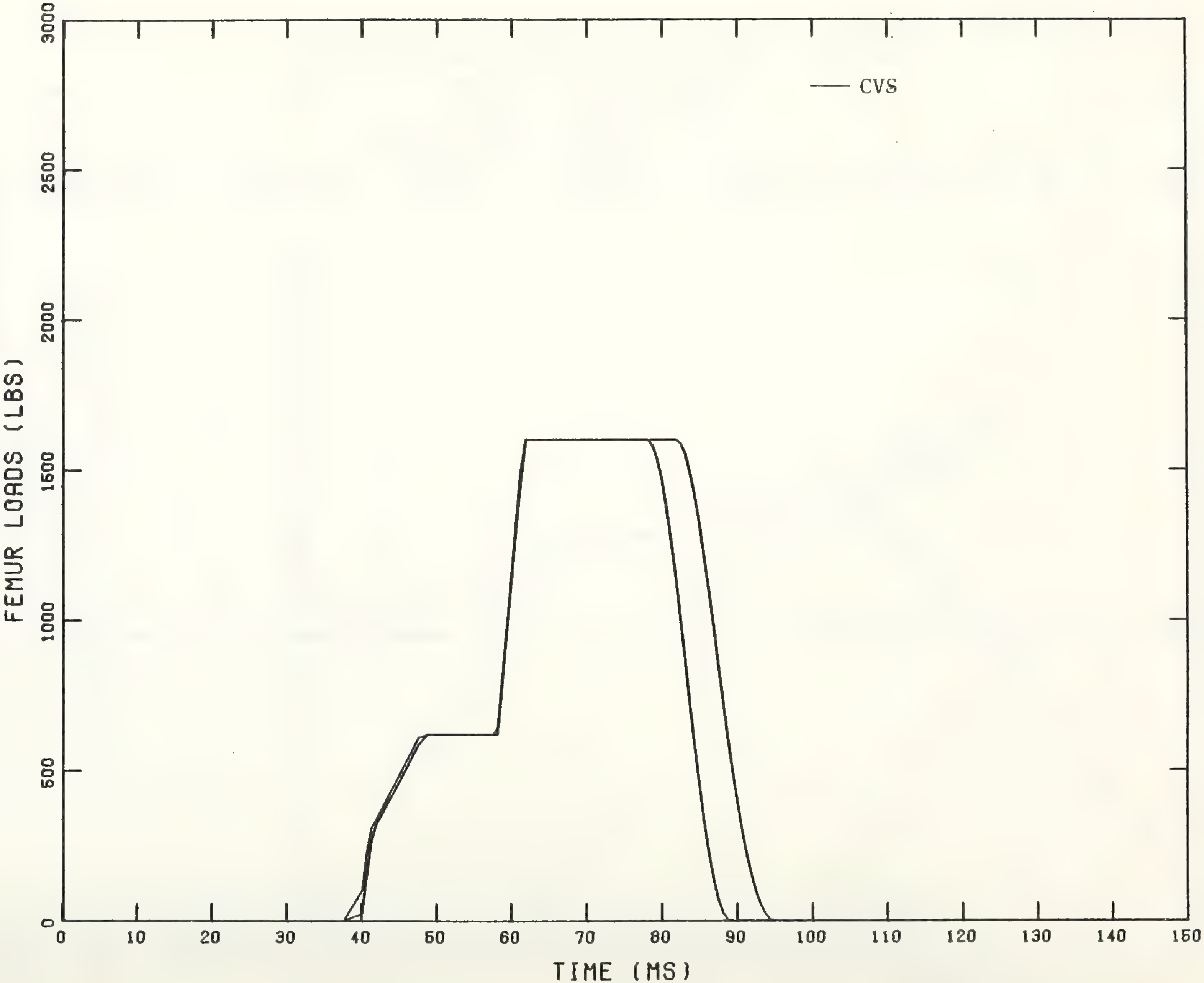
CHEST RESULTANT ACCELERATION VS. TIME
SIMULATION OF 14 DEGREE RUN (R14DEG - TASK 4)



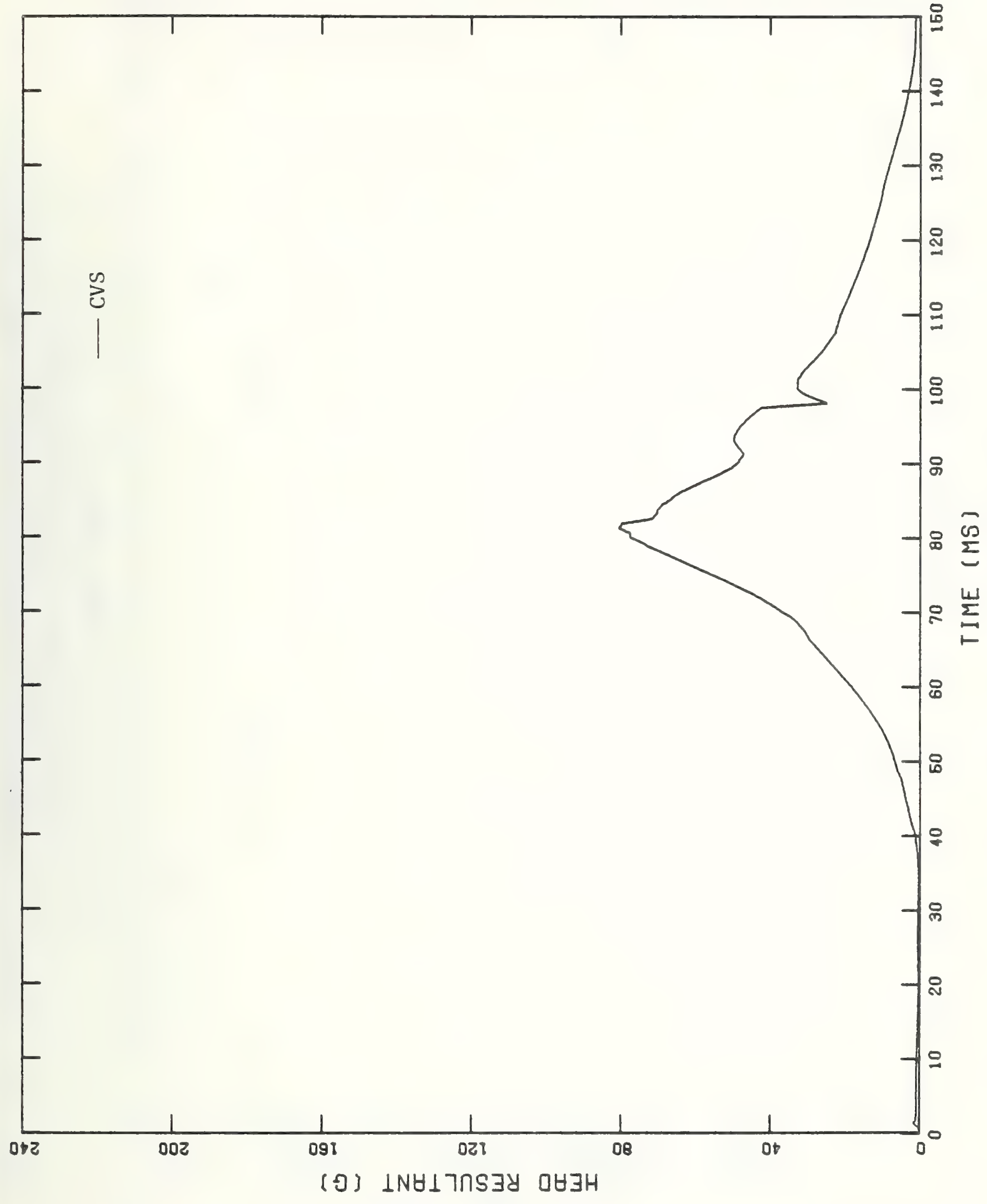
BELT LOADS VS. TIME
SIMULATION OF 14 DEC RUN (R14DEC TASK 4)



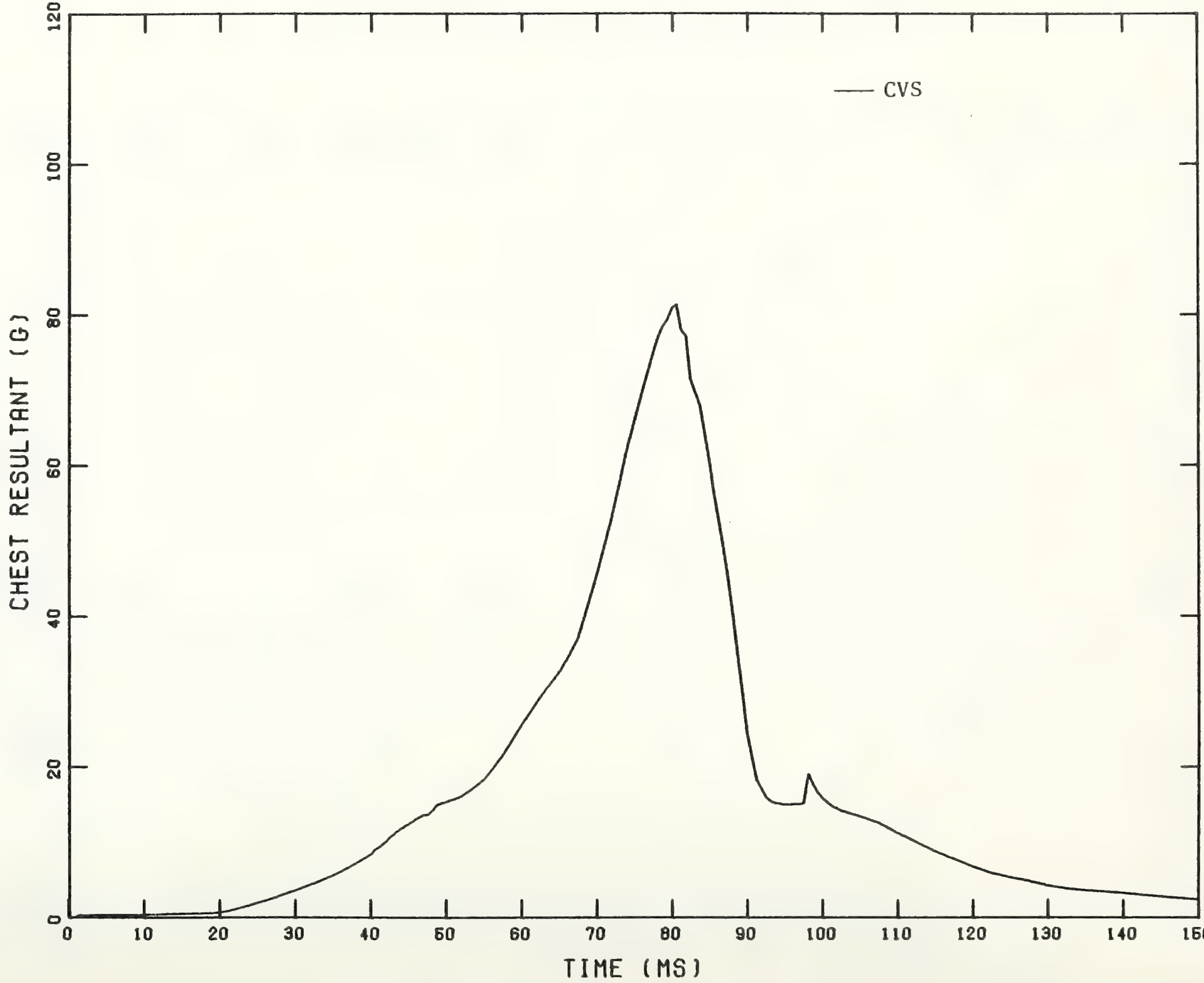
HEAD X VS. HEAD Y DISPLACEMENT
SIMULATION OF 14 DEG RUN (R14DEG TASK 4)



RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF 14 DEGREE RUN (R14DEG - TASK 4)

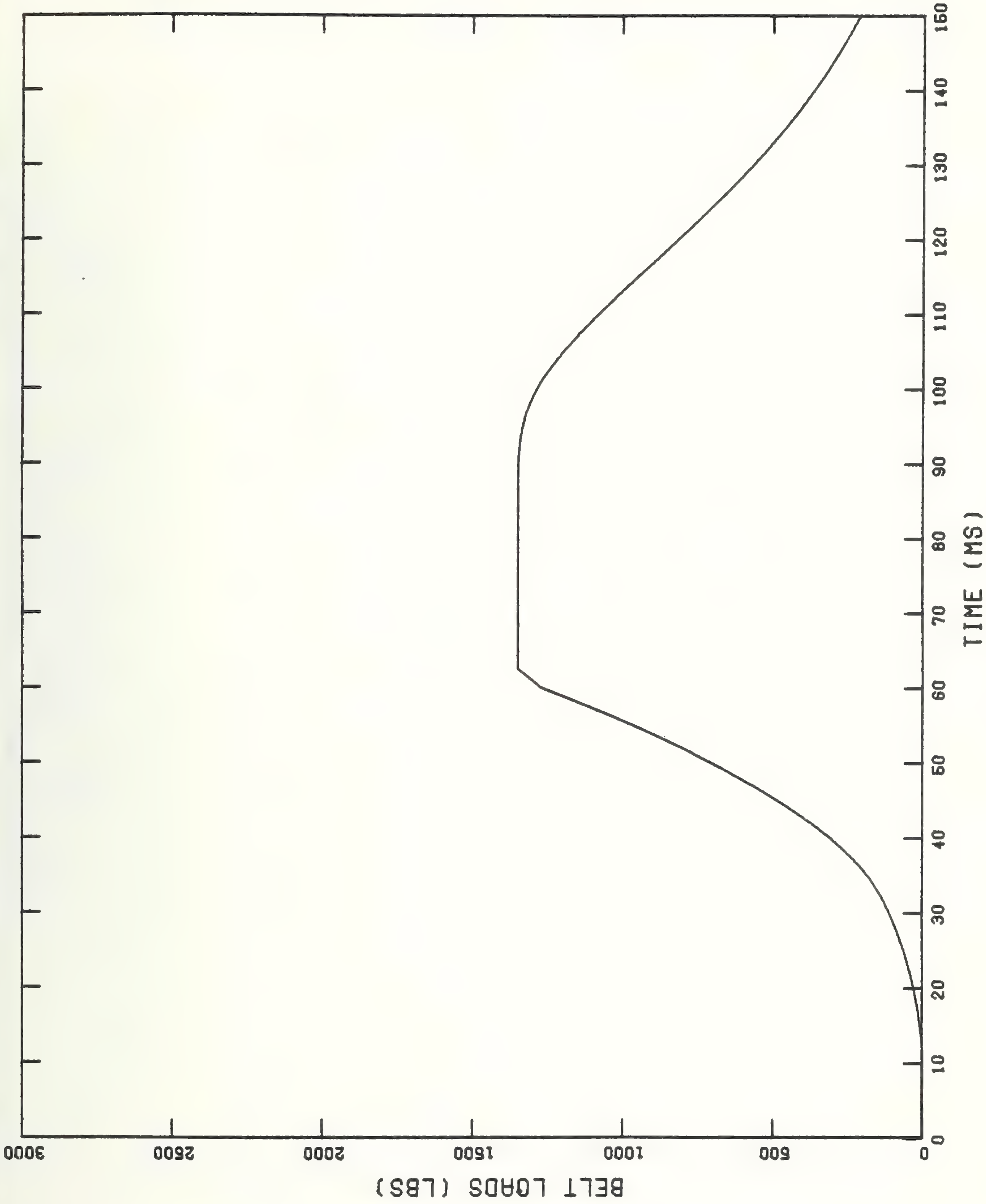


HEAD X VS. HEAD Y DISPLACEMENT
SIMULATION OF 30 DEG RUN (R30DEG TASK 4)

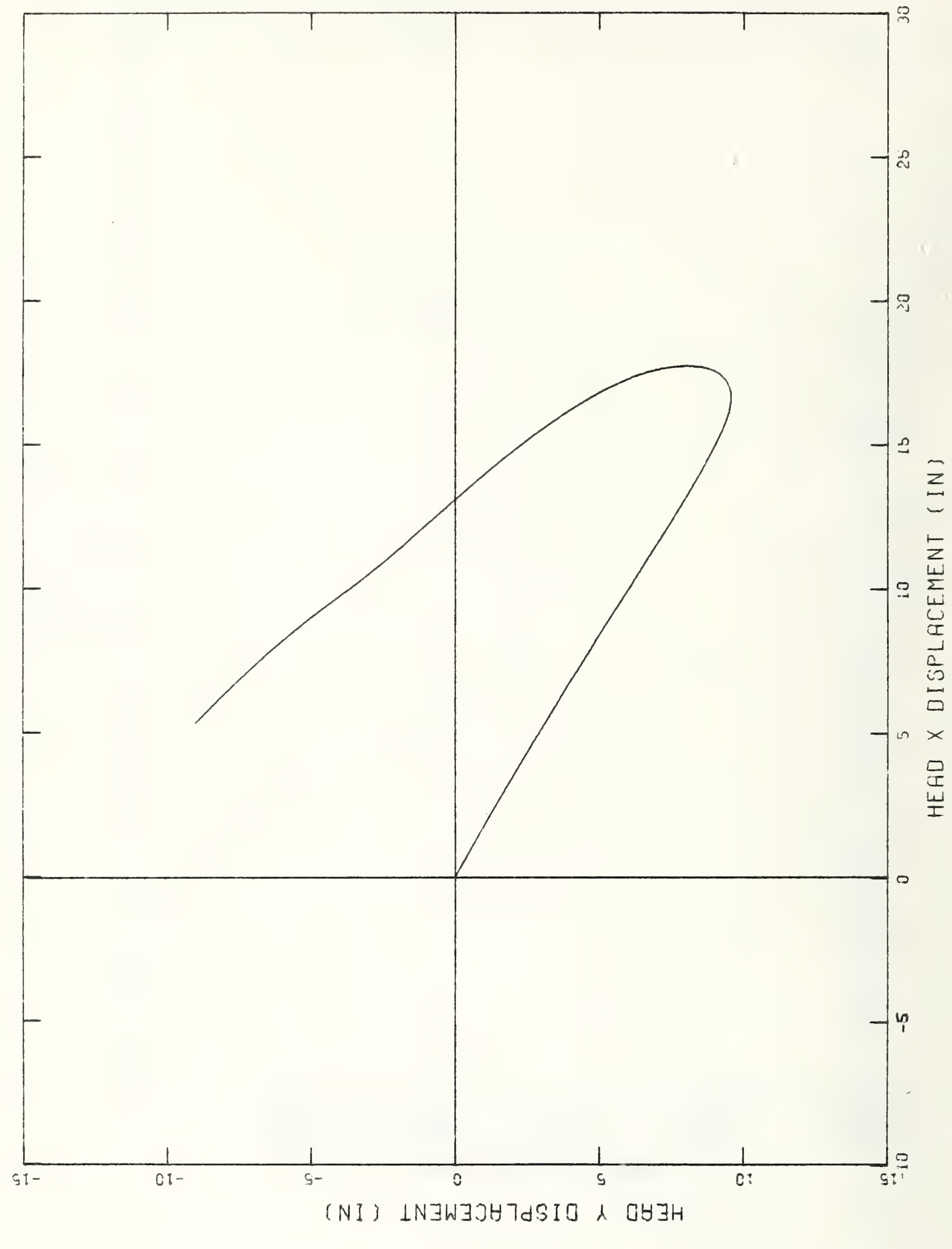


CHEST RESULTANT ACCELERATION VS.TIME

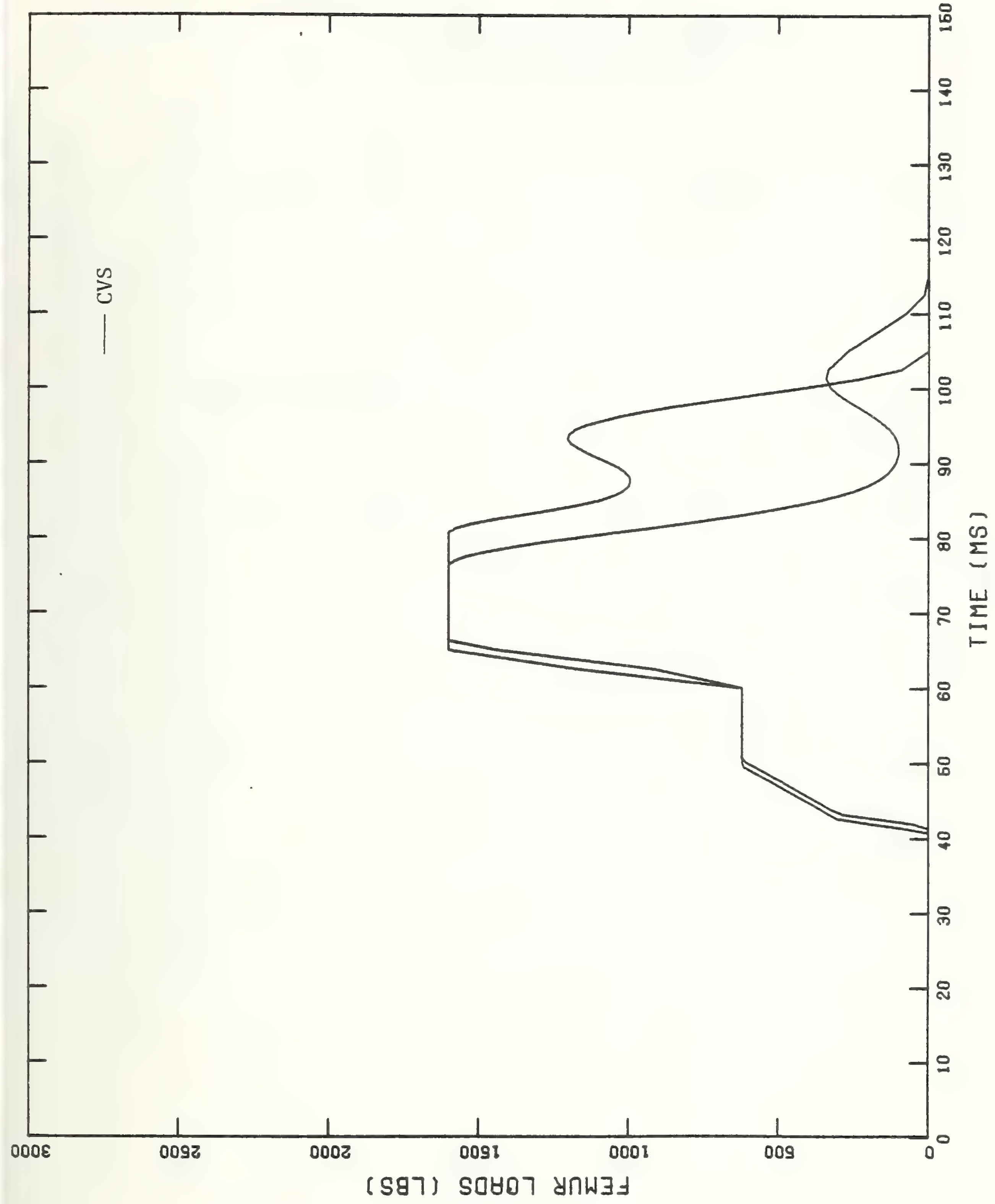
SIMULATION OF 30 DEGREE RUN (R30DEG - TASK 4)



BELT LOADS VS. TIME
SIMULATION OF 30 DEG RUN (R30DEG TASK 4)



HEAD X VS. HEAD Y DISPLACEMENT
SIMULATION OF 30 DEG RUN (R30DEG TASK 4)



RIGHT AND LEFT FEMUR LOADS VS. TIME
SIMULATION OF 30 DEGREE RUN (R30DEG - TASK 4)

SELECTED EXAMPLES OF UNIVAC COMMAND LANGUAGE
NECESSARY TO ACCESS SIMULATION DATA
STORED AT EDGEWOOD, MARYLAND

The following command language will move a data file from tape to disk and create output. User-supplied names are indicated by lower case letters.

This example moves file 11 (U82029A) from tape 2338P4 to a disk file and outputs tabular time histories:

```
@RUN          run-id,account/user-id,project,runtime,pages
@PASSWD       password
@BOX
@SYM          PRINTØ,,RMTSxx      (xx - remote site-id)
@MSG,W        PLEASE MOUNT TAPE 2338P4.
@DELETE,C     disk-filename.
@ASG,UP       disk-filename.
@ASG,T        tape-filename.,8C,2338P4
@MOVE         tape-filename.,10
@COPY,G       tape-filename.,disk-filename.
@USE          8,disk-filename.
@ASG,AX       CALSPAN*CVS3PROG.
@XQT          CALSPAN*CVS3PROG.VER18C
@FIN
```

The following command language will create output unit 8, printer plots, tabular time histories and plots from a disk input element:

```
@RUN          run-id,account/user-id,project,runtime,pages
@PASSWD       password
@BOX
@SYM          PRINT$,,RMTSxx
@DELETE,C     U2runid.
@ASG,UP       U2runid.
@USE          2,U2runid.
@DELETE,C     U8runid.
@ASG,UP       U8runid.
@USE          8, U8runid.
@DELETE,C     U9runid.
@ASG,UP       U9runid.
@USE          U9runid.
@ASG,A        BKFILE2.
@PRT          BKFILE2.runid
@ASG,AX       CALSPAN*CVS3PROG.
@XQT          CALSPAN*CVS3PROG.VER18C
@ADD,PE       BKFILE2.runid
@BRKPT        2
@FREE         U2runid.
@SYM          U2runid,,RMTSxx
@PLOT,N       U9runid.
@MSG,W        SEE MAIL ADDRESS ON PLOT.
@FIN
```

The following command language will create tabular time histories and plots from an existing unit 8 disk file. Cards A, H and I are CVS III input cards and are described in Reference

```
@RUN          run-id,account/user-id,project,runtime,pages
@PASSWORD     password
@BOX
@SYM          PRINT$,,RMTSxx
@ASG,A        U8runid.
@USE          8,U8runid.
@DELETE,C     U9runid.
@ASG,UP       U9runid.
@USE          9,U9runid.
@ASG,AX       CALSPAN*CVS3PROG.
@XQT          CALSPAN*CVS3PROG.VER18C
      CVS III Input Deck
CARDS A
CARD H8
CARDS I
@PLOT,N       U9runid.
@MSG,W        SEE MAIL ADDRESS ON PLOT.
@FIN
```

APPENDIX C

BIBLIOGRAPHY

This appendix contains a bibliography of reports related to the subject of occupant protection using preloaded or load limited safety belts. The bibliography was supplied by the Contract Technical Manager, Carl Clark, through his search of the NHTSA "Highway Safety Literature" computer file maintained by Informatics, Inc. for inclusion in this final technical report.

The abbreviations are as follows:

< DAT >	Report Date
< AUT >	Author
< COR >	Corporate Authors
< TTL >	Report Title
< ACC >	= < FIL > Accession number in coded form. For example < FIL > DOT 02H31120 is NHTSA Report DOT HS-023112.
< CIT >	Citation to a serial or journal
< SUP >	Supplementary Note
< COL >	Collation Detail - number of pages and references used
< REP >	Report Number if given a non-NHTSA report number
< AVA >	Availability - whom to write for the report
< ISS >	Issue of the monthly NHTSA abstract journal "Highway Safety Literature" containing the abstract
< CON >	Contract Number
< REF >	Docket Reference
< ABS >	Abstract.

PRINT 21/4/1-33 TERMINAL=03

R<DAT> 1977 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221
R<TTL> RESEARCH SAFETY VEHICLE (RSV). PHASE 3. STATUS REPORT NO. 3
<FIL>DOTI 80H25140 R<ISS> 77-12

R<DAT> 1977 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221
R<TTL> RESEARCH SAFETY VEHICLE (RSV). PHASE 3. FIRST STATUS REPORT
<FIL>DOTI 80H24030 R<ISS> 77-11

R<DAT> 1977 R<AUT> DANNER, J. MAXIMILIAN R<COR> ALLIANZ-VERSICHERUNGS AG, GERMANY
R<TTL> ACCIDENT AND INJURY CHARACTERISTICS IN SIDE-COLLISIONS AND PROTECTION CRITERIA IN RESPECT OF BELTED OCCUPANTS
<FIL>DOTI 02H17860 R<ISS> 78-04

R<DAT> 1977 R<AUT> HONTSCHIK, HEINRICH; MULLER, EGBERT; RUTER, GERT R<COR> BATTELLE-INSTITUT E.V., FRANKFURT AM MAIN, GERMANY
R<TTL> NECESSITIES AND POSSIBILITIES OF IMPROVING THE PROTECTIVE EFFECT OF THREE-POINT SEAT BELTS
<FIL>DOTI 02H18000 R<ISS> 78-04

R<DAT> 1977 R<AUT> SHAH, M. P. R<COR> TRANSPORTATION RES. CENTER OF OHIO, EAST LIBERTY, OHIO 43319
R<TTL> PERFORMANCE EVALUATION OF 50TH PERCENTILE INTERNATIONAL TEST DUMMIES. VOL. 1. FINAL REPORT
<FIL>DOTI 80H22130 R<ISS> 77-07

R<DAT> 1977 R<AUT> STALNAKER, R. L. R<COR> UNIVERSITY OF MICHIGAN, HWY. SAFETY RES. INST.
R<TTL> SURVEY OF THE PERFORMANCE OF INFANT AUTO RESTRAINT SYSTEMS SOLD IN THE UNITED STATES AND CANADA. FINAL REPORT
<FIL>DOTI 02H06960 R<ISS> 77-09

R<DAT> 1976 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221
R<TTL> RESEARCH SAFETY VEHICLE (RSV) CRASH TEST REPORT. RSV TEST NO. 11. PLYMOUTH FURY VS. RSV, HEAD-ON FRONTAL IMPACT, 40 MPH EACH VEHICLE
<FIL>DOTI 80H22030 R<ISS> 77-06

R<DAT> 1976 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221
R<TTL> RESEARCH SAFETY VEHICLE (RSV) CRASH TEST REPORT. RSV TEST NO. 5. 45 MPH FLAT BARRIER FRONTAL IMPACT
<FIL>DOTI 80H21980 R<ISS> 77-06

PAGE 1 (ITEMS 1- 8 OF 33)

R<DAT> 1976 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221
R<TTL> RESEARCH SAFETY VEHICLE (RSV) CRASH TEST REPORT. RSV TEST NO. 7. RSV VS. RSV, CAR-TO-CAR OFFSET, 40 MPH EACH VEHICLE
<FIL>DOTI 80H21990 R<ISS> 77-06

R<DAT> 1976 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221
R<TTL> RESEARCH SAFETY VEHICLE (RSV) CRASH TEST REPORT. TEST: MOD. B (MODIFIED BASELINE VEHICLE). TYPE OF TEST: BARRIER CRASHES (NO DAMAGE - 5 MPH FOLLOWED BY 35 MPH)
<FIL>DOTI 80H21260 R<ISS> 77-04

R<DAT> 1976 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221
R<TTL> RESEARCH SAFETY VEHICLE (RSV) PHASE 2. STATUS REPORT NO. 4, 16 JANUARY TO 15 MARCH 1976
<FIL>DOTI 80H18570 R<ISS> 76-08

R<DAT> 1976 R<AUT> BABBITT, RICHARD G.; HENDERSON, CYRIL R<COR> AMERICAN SAFETY EQUIPMENT CORP.
R<TTL> NEW DEVELOPMENTS IN SAFETY BELT DESIGN
<FIL>DOTI 02H01750 R<ISS> 77-05

R<DAT> 1976 R<AUT> KALLERIS, D.; BARZ, J.; SCHMIDT, G.; HEESS, G.; MATTERN, R. R<COR> UNIVERSITY OF HEIDELBERG, WEST GERMANY
R<TTL> COMPARISON BETWEEN CHILD CADAVERS AND CHILD DUMMY BY USING CHILD RESTRAINT SYSTEMS IN SIMULATED COLLISIONS
<FIL>DOTI 02H01490 R<ISS> 77-05

R<DAT> 1976 R<AUT> QUINCY, R.; DEJEAMMES, M. R<COR> ONSER--LABORATOIRE DES CHOCS ET DE BIOMECANIQUE, 109 AV. SALVADOR ALLENDE, 69500
R<TTL> ANALYSIS OF THE PRELOADED SAFETY BELT RESTRAINT WITH AN ANIMAL
<FIL>DOTI 02H02540 R<ISS> 77-06

R<DAT> 1976 R<AUT> SEIFFERT, U. R<COR> VOLKSWAGENWERK AG, GERMANY
R<TTL> RESTRAINT SYSTEMS FOR OCCUPANT PROTECTION
<FIL>DOTI 01H88450 R<ISS> 76-11

R<DAT> 1976 R<AUT> SHAH, MAHESH P.; RADOVICH, VLADISLAV G. R<COR> TRANSPORTATION RES. CENTER OF OHIO, EAST LIBERTY, OHIO 43319; NATIONAL HWY. TRAFFIC SAFETY ADMINISTRATION, WASHINGTON, D.C. 20590
R<TTL> PERFORMANCE EVALUATION OF CHILD TEST DUMMIES. VOL. 2: APPENDIX. FINAL REPORT
<FIL>DOTI 80H19220 R<ISS> 76-11

PAGE 2 (ITEMS 9- 16 OF 33)

R<DAT> 1976   R<AUT> WALL, J.; LOWNE, R. W.; HARRIS, J.   R<COR>
DEPARTMENT OF THE ENVIRONMENT, TRANSPORT AND RD. RES.
R<TTL> THE DETERMINATION OF TOLERABLE LOADINGS FOR CAR OCCUPANTS IN IMPACTS
<FIL>DOTI 01H95910   R<ISS> 77-03

R<DAT> 1976   R<AUT> WASKI, HENRY J.   R<COR> TIMKEN CO.
R<TTL> WHEEL BEARING MOUNTINGS FOR HIGHWAY VEHICLES
<FIL>DOTI 02H03650   R<ISS> 77-07

R<DAT> 1975   R<COR> AUTO RESTRAINTS SYSTEMS, LTD., ENGLAND
R<TTL> A REVIEW OF DEVELOPMENT OF PASSIVE RESTRAINT SYSTEMS
<FIL>DOTI 01H65960   R<ISS> 75-10

R<DAT> 1975   R<AUT> DEJEAMMES, M.; QUINCY, R.   R<COR> ORGANISME NATIONAL DESECURITE ROUTIERE (ONSER), LABORATOIRE DES CHOCS, FRANCE
R<TTL> EFFICIENCY COMPARISON BETWEEN THREE-POINT BELT AND AIR BAG IN A SURCOMPACT VEHICLE
<FIL>DOTI 01H81040   R<ISS> 76-06

R<DAT> 1975   R<AUT> HARTEMANN, F.; TARRIERE, C.; MACKAY, G. M.; GLOYNS, P. F.; HAYES, H. R. M.; CESARI, M., D., M. RAMET   R<COR>
ASSOCIATION PEUGEOT-RENAULT, LAB. DE PHYSIOLOGIE ET DE BIOMECANIQUE, FRANCE; UNIVERSITY OF BIRMINGHAM, DEPT. OF TRANSPORTATION AND ENVIRONMENTAL PLANNING, EN O.N.S.E.R. (LYON), LABORATOIRE DES CHOCS ET DE BIOMECANIQUE, FRANCE
R<TTL> HOW TO FURTHER IMPROVE THE PROTECTION OF OCCUPANTS WEARING SEAT BELTS
<FIL>DOTI 01H79510   R<ISS> 76-06

R<DAT> 1975   R<AUT> KALLIERIS, D.; MEISTER, B.; SCHMIDT, G.   R<COR>
UNIVERSITY HEIDELBERG, INST. FOR FORENSIC MEDICINE
R<TTL> REACTIONS OF THE CERVICAL SPINE DURING FRONTAL IMPACTS OF BELT PROTECTED CADAVERS
<FIL>DOTI 01H80700   R<ISS> 76-06

R<DAT> 1975   R<AUT> MELVIN, JOHN W.; STALNAKER, RICHARD L.   R<COR>
UNIVERSITY OF MICHIGAN, HWY. SAFETY RES. INST.
R<TTL> PRACTICAL ASPECTS OF CHILD SAFETY RESTRAINT SYSTEM STANDARDS
<FIL>DOTI 01H71390   R<ISS> 76-01

R<DAT> 1975   R<AUT> SHOEMAKER, N. E.; RYDER, M. O.; DELEYS, N. J.
R<COR> CALSPAN CORP., 4455 GENESSEE ST., BUFFALO, N.Y. 14221
R<TTL> CONSUMER INFORMATION CRASH TEST PROGRAM PREDICTION OF DYNAMIC CRASH RESPONSES FOR VEHICLE AND OCCUPANTS. FINAL TECHNICAL REPORT, VOL. 1
<FIL>DOTI 80H30370   R<ISS> 78-05

PAGE   3   (ITEMS 17- 24 OF 33)

R<DAT> 1974 R<AUT> KALLIERIS, DIMITRIOS; MATTERN, RAINER R<COR> UNIVERSITY OF HEIDELBERG, INST. OF FORENSIC
R<TTL> SHOULDER-BELT-FORCES AND THORAX INJURIES
<FIL>DOTI 01H76100 R<ISS> 76-04

R<DAT> 1974 R<AUT> MACKAY, G. M.
R<TTL> SOME COST BENEFIT CONSIDERATIONS OF CAR OCCUPANT RESTRAINT SYSTEMS
<FIL>DOTI 01H67780 R<ISS> 75-11

R<DAT> 1974 R<AUT> SCHIMKAT, H. J. R<COR> VOLKSWAGENWERK A. G., WOLFSBURG (WEST GERMANY)
R<TTL> THEORETICAL AND EXPERIMENTAL INVESTIGATIONS ON THE CRASHWORTHINESS OF SMALL CARS
<FIL>DOTI 01H56790 R<ISS> 75-05

R<DAT> 1974 R<AUT> STALNAKER, R. L.; MELVIN, J. W. R<COR> UNIVERSITY OF MICHIGAN, HWY. SAFETY RES. INST.
R<TTL> BASIC DESIGN PRINCIPLES OF CHILD AUTO RESTRAINTS
<FIL>DOTI 01H73220 R<ISS> 76-02

R<DAT> 1972 R<AUT> FIALA, E. R<COR> VOLKSWAGENWERK A.G., WOLFSBURG (WEST GERMANY)
R<TTL> THE VOLKSWAGEN ESV
<FIL>DOTI 01H35400 R<ISS> 73-24

R<DAT> 1972 R<AUT> MCELHANEY, J. H.; ROBERTS, V. L. R<COR> MICHIGAN UNIV. HWY. SAFETY RES. INST.
R<TTL> DYNAMIC PERFORMANCE OF CHILD SEATING SYSTEMS
<FIL>DOTI 01H23930 R<ISS> 73-07

R<DAT> 1972 R<AUT> ROBERTS, V. L.; MCELHANEY, J. H.; MELVIN, J. W.; SHELTON, W.; HAMMOND, A. J. R<COR> FORD MOTOR CO.
R<TTL> BIOMECHANICS OF SEAT BELT DESIGN
<FIL>DOTI 01H23940 R<ISS> 73-07

R<DAT> 1972 R<AUT> WILLUMEIT, H. P. R<COR> VOLKSWAGENWERK A. G. (WEST GERMANY)
R<TTL> PASSIVE PRELOADED ENERGY-ABSORBING SEAT BELT SYSTEM. IMPROVED BELT SYSTEMS
<FIL>DOTI 01H17730 R<ISS> 72-21

R<DAT> 1969 R<AUT> FOSTER, D.; STOW, E. W. T. R<COR> KNOWHOW LTD., LONDON (ENGLAND)
R<TTL> THE CUSHION CAR - A NEW APPROACH TO AN INTRINSICALLY SAFE MOTOR-CAR
<FIL>DOTI 01H41680 R<ISS> 00-00

PRINT 43/4/1-39 TERMINAL=01

R<DAT> 1978 R<TTL> OCCUPANT PROTECTION: AN INTEGRATED APPROACH
<FIL>DOTI 02H31120 R<CIT> AUTOMOTIVE ENGINEERING V86 N5 P26-31
(MAY 1978) R<SUP> BASED ON SAE-780282 "PASSIVE VEHICLE SAFETY AS CARS GROW SMALLER," BY H. SCHIMKAT AND R. WEISSNER, AND SAE-780414 "A COMPARISON OF ADVANCED BELT SYSTEMS REGARDING THEIR EFFECTIVENESS," BY R. WEISSNER; PRESENTED AT SAE CONGRESS, DETROIT, 27 FEB-3 MAR 1978.
R<COL> 3REFS R<AVA> SEE PUBLICATION R<ISS> 78-10

R<ABS> THEORETICAL AND EMPIRICAL STUDIES BY VOLKSWAGEN ENGINEERS TO INVESTIGATE THE COMPLEX INTERACTIONS OF VEHICLE STRUCTURES AND PASSENGER RESTRAINT SYSTEMS IN ORDER TO OPTIMIZE SMALL-CAR OCCUPANT PROTECTION ARE REPORTED. THE FRONTAL IMPACT STUDIES SHOW THE IMPORTANCE OF A BALANCE BETWEEN STRUCTURAL DEFORMATION AND INTEGRITY, AND OF RESTRAINT DEVICES THAT PRELOAD AND LIMIT FORCES ON THE OCCUPANTS. THE INVESTIGATIONS FOCUS ON SEATBELT SYSTEMS, PARTICULARLY VW'S PASSIVE RESTRAINT CONCEPT. FOUR DIFFERENT RESTRAINT CONFIGURATIONS WERE STUDIED. ONE WAS AN ACTIVE THREE-POINT BELT; THE OTHER THREE, VARIATIONS ON A PASSIVE SHOULDER BELT/KNEE-BOLSTER THEME. THE THREE-POINT SYSTEM WAS FITTED WITH BOTH A PRELOADING DEVICE AND A BELT FORCE LIMITER. PASSIVE SYSTEMS WERE TESTED IN THREE FORMS, WITH LIMITER AND PRELOADER, WITH LIMITER ALONE, AND WITH NEITHER DEVICE. PARAMETERS MODELED IN THE THEORETICAL WORK INCLUDED PASSENGER COMPARTMENT ACCELERATION, OCCUPANT ACCELERATION, AND REACTION TIME OF THE RESTRAINT SYSTEM MEASURED FROM THE ONSET OF COMPARTMENT ACCELERATION. TWO SERIES OF SLED TESTS USING A 50TH PERCENTILE MALE DUMMY IN A FRONT PASSENGER POSITION WERE RUN. THE FIRST COMPARED SHOULDER BELT/KNEE BOLSTER COMBINATIONS IN THE THREE DIFFERENT FORMS. THESE TESTS SIMULATED 50 KM/H IMPACTS AGAINST A FIXED BARRIER; SLED DECELERATIONS WERE AROUND 25 G. THE SECOND SERIES COMPARED AN ACTIVE THREE-POINT BELT WITH THE PASSIVE RESTRAINT; BOTH SYSTEMS HAD FORCE LIMITER AND PRELOADER. SIMULATED IMPACT SPEEDS WERE 64 KM/H WITH SLED DECELERATIONS OF AROUND 27 G. RESULTS CONFIRM WHAT IS PERCEIVED AS ONE OF THE PRINCIPAL ADVANTAGES OF THE BELT/BOLSTER SYSTEM, I.E., KINEMATICS THAT SUBSTITUTE SOME FORWARD MOVEMENT OF THE LOWER TORSO IN PLACE OF POTENTIALLY MORE HAZARDOUS HEAD DISPLACEMENT. ALSO, THE BENEFICIAL INFLUENCES OF FORCE LIMITING AND PRELOADING ARE SHOWN. AN EVALUATION INDEX, EI, DESIGNED TO HELP QUANTIFICATION OF THE MANY VARIABLES INFLUENCING OCCUPANT PROTECTION IS PRESENTED AND DISCUSSED. GIVEN EQUIVALENT TEST CONDITIONS, THE EI CAN BE USED TO EVALUATE VARIATIONS ON A GIVEN RESTRAINT THEME, OR IT CAN BE USED TO COMPARE ONE SYSTEM TYPE WITH ANOTHER.

R<DAT> 1977 R<COR> DYNAMIC SCIENCE INC., 1850 W. PINNACLE PEAK RD., PHOENIX, ARIZ. 85027 R<TTL> VEHICLE INTEGRATION AND EVALUATION OF ADVANCED RESTRAINT SYSTEMS. PHASE A - TEST REPORT. VOLVO-TO-VOLVO, VOLVO-TO-BARRIER TESTS

<FIL>DOTI 80H28290 R<SUP> PHASE B REPT. IS HS-802 830. R<COL> 464P R<REP> DSI-8300-77-146 R<AVA> REFERENCE COPY ONLY R<ISS> 78-03 R<CON> DOT-HS-6-01307 R<REF> DOC-74-14 R<ABS> NINE IMPACT TESTS WERE PERFORMED WITH VOLVO 244'S IN CAR-TO-CAR AND CAR-TO-BARRIER CONFIGURATIONS TO TEST THE RESEARCH SAFETY VEHICLE (RSV) DRIVER RESTRAINT SYSTEM, THE RSV PASSENGER AIRBAG SYSTEM, THE FORCE-LIMITED AIRBELT, AND THE FORCE-LIMITED TWO-INCH BELT. THE CAR-TO-CAR TESTS (HEAD-ON AND OFFSET RIGHT AND LEFT) WERE PERFORMED WITH CLOSING SPEEDS OF FROM 80.6 TO 89.8 MPH, BOTH CARS MOVING AT THE SAME SPEED; THE BARRIER IMPACT TEST SPEEDS RANGED FROM 46.1 TO 48.3 MPH. IN THE MAJORITY OF THE TESTS THE RSV DRIVER AIRBAG AND THE RSV PASSENGER AIRBAG WERE INSTALLED IN ONE CAR AND THE FORCE-LIMITED AIR BELT AND FORCE-LIMITED TWO-INCH BELT IN THE SECOND. BOTH WERE TREATED AS PASSENGER RESTRAINT SYSTEMS, I.E. NO STEERING COLUMN AT EITHER POSITION. THE VEHICLES WERE STRUCTURALLY MODIFIED TO PROVIDE MOUNTING HARDWARE FOR THE RESTRAINT SYSTEMS AND TO RETAIN THE STRUCTURAL INTEGRITY OF THE OCCUPANT COMPARTMENT, PARTICULARLY IN THE COWLING REGION. FOR EACH TEST, IMPACT CONDITIONS AND VEHICLE MODIFICATIONS ARE DESCRIBED, AND TABULATED SUMMARIES ARE GIVEN OF VEHICLE DATA, INJURY CRITERIA DATA, RESTRAINT SYSTEM DATA, AND OCCUPANT RESPONSE DATA. DATA GATHERED INCLUDED PEAK G'S FOR HEAD, CHEST, AND FEMURS, AND VELOCITY CHANGE IN MPH.

R<DAT> 1977 R<COR> DYNAMIC SCIENCE INC., 1850 W. PINNACLE PEAK RD., PHOENIX, ARIZ. 85027 R<TTL> VEHICLE INTEGRATION AND EVALUATION OF ADVANCED RESTRAINT SYSTEMS. PHASE B - TEST REPORT. TORINO-TO-VOLVO TESTS

<FIL>DOTI 80H28300 R<SUP> PHASE A REPT. IS HS-802 829. R<COL> 221P R<REP> DSI-8300-77-147 R<AVA> REFERENCE COPY ONLY R<ISS> 78-03 R<CON> DOT-HS-6-01307 R<REF> DOC-74-14 R<ABS> EIGHT IMPACT TESTS WERE CONDUCTED WITH VOLVO 244'S AS IMPACT VEHICLES AND FORD TORINOS AS BULLET VEHICLES TO TEST THE RESEARCH SAFETY VEHICLE (RSV) DRIVING RESTRAINT SYSTEM, THE RSV PASSENGER AIRBAG SYSTEM, THE FORCE-LIMITED AIRBELT, AND THE FORCE-LIMITED TWO-INCH BELT. THE TORINO-TO-VOLVO IMPACTS WERE HEAD-ON AND AT ANGLES RANGING FROM ZERO TO 45¢. IMPACT SPEEDS RANGED FROM 59.5 TO 78.6 MPH. THE RSV DRIVER AND PASSENGER AIRBAGS WERE INSTALLED TOGETHER IN ONE TEST VEHICLE AND THE FORCE LIMITED AIRBELT AND FORCE LIMITED TWO-INCH BELT IN THE SECOND. BOTH WERE TREATED AS PASSENGER RESTRAINT SYSTEMS, I.E. NO STEERING COLUMN AT EITHER POSITION. THE VEHICLES WERE STRUCTURALLY MODIFIED TO PROVIDE MOUNTING HARDWARE FOR THE RESTRAINT SYSTEMS AND TO RETAIN THE STRUCTURAL INTEGRITY OF THE OCCUPANT COMPARTMENT, PARTICULARLY IN THE COWLING REGION. FOR EACH TEST, IMPACT CONDITIONS AND VEHICLE MODIFICATIONS ARE DESCRIBED, AND TABULATED SUMMARIES ARE GIVEN OF VEHICLE DATA, INJURY CRITERIA DATA, RESTRAINT SYSTEM DATA, AND OCCUPANT RESPONSE DATA. DATA GATHERED INCLUDED PEAK G'S FOR HEAD, CHEST, AND FEMURS, AND VELOCITY CHANGE IN MPH.

R<DAT> 1977 R<AUT> CARR, R. W.; ABOUD, G. M. R<COR> DYNAMIC SCIENCE INC., 1850 W. PINNACLE PEAK RD., PHOENIX, ARIZ. 85027 R<TTL> THE EVALUATION OF 1975 TORINO TYPE 2 BELT RESTRAINT SYSTEMS WITH WEB LOCKING AND FORCE LIMITING FEATURES. TEST REPORT
<FIL>DOTI 80H33960 R<SUP> REPT. FOR SEP 1976-SEP 1977. R<COL> 213P R<REP> DSI-8300-77-184 R<AVA> CORPORATE AUTHOR R<ISS> 78-12 R<CON> DOT-HS-6-01307 R<REF> DOC-74-14 R<ABS> DATA FROM CAR CRASH TESTS ON FORD TORINOS (PHASE C OF A TEST SERIES), CONDUCTED TO EVALUATE THE PERFORMANCE OF ADVANCED RESTRAINT SYSTEMS IN MEETING FEDERAL MOTOR VEHICLE SAFETY STANDARD 208, OCCUPANT CRASH PROTECTION, INJURY CRITERIA, ARE PRESENTED. THREE VARIATIONS OF THE STANDARD FORD TORINO BELT SYSTEMS WERE TESTED AND THE DESIGNATION APPLIED TO EACH RESTRAINT SYSTEM WAS: STANDARD THREE-POINT BELT SYSTEM, STANDARD THREE-POINT BELT SYSTEM WITH WEB LOCKERS, STANDARD THREE-POINT BELT SYSTEM WITH WEB LOCKERS AND FORCE LIMITERS, AND STANDARD THREE-POINT BELT SYSTEM WITH WEB LOCKERS AND TEAR WEBBING. THE STANDARD RESTRAINT SYSTEMS, THE WEB LOCKING MECHANISMS, AND TEAR WEBBING WERE SUPPLIED BY ALLIED CHEMICAL, THE ORIGINAL EQUIPMENT MANUFACTURER FOR THE RESTRAINT SYSTEMS IN THE FORD TORINOS USED. ALSO, EACH STANDARD THREE-POINT BELT SYSTEM WAS FURNISHED WITH POLYESTER WEBBING INSTEAD OF THE NYLON WEBBING ORIGINALLY SUPPLIED. WITH THE EXCEPTION OF A MOUNTING BRACKET ON THE B-PILLAR FOR THE WEB LOCKING MECHANISM, THE FORD TORINOS WERE NOT MODIFIED IN ANY MANNER. THE MATRIX OF IMPACT CONDITIONS COVERED, A SUMMARY OF TEST RESULTS, AND COMPLETE DATA FROM EACH TEST ARE PRESENTED.

R<DAT> 1977 R<AUT> CARR, R. W.; ABOUD, G. M. R<COR> DYNAMIC SCIENCE, INC., 1850 W. PINNACLE PEAK RD., PHOENIX, ARIZ. 85027 R<TTL> VEHICLE INTEGRATION AND EVALUATION OF ADVANCED RESTRAINT SYSTEMS. VOL. 3: PHASE C. THE EVALUATION OF 1975 TORINO TYPE 2 BELT RESTRAINT SYSTEMS WITH WEB LOCKING AND FORCE LIMITING FEATURES. FINAL REPORT

<FIL>DOTI 80H35940 R<SUP> REPT. FOR SEP 1976-SEP 1977. R<COL> 214P R<REP> 8300-77-184 R<AVA> NTIS R<ISS> 79-05 R<CON> DOT-HS-6-01307 R<ABS> IN THE THIRD PHASE OF A SERIES OF 18 FULL-SCALE CAR CRASH TESTS TO EVALUATE THE PERFORMANCE OF RESTRAINT SYSTEMS IN TERMS OF MEETING THE FEDERAL MOTOR VEHICLE SAFETY STANDARD NO. 208 INJURY CRITERIA, FORD TORINOS WERE TESTED USING INSTRUMENTED DUMMIES RESTRAINED BY BOTH STANDARD AND MODIFIED BELT SYSTEMS (STANDARD 3-POINT BELT SYSTEM, STANDARD 3-POINT BELT SYSTEM WITH WEB LOCKERS, STANDARD 3-POINT BELT SYSTEM WITH WEB LOCKERS AND FORCE LIMITERS, AND STANDARD 3-POINT BELT SYSTEM WITH WEB LOCKERS AND TEAR WEBBING). WITH THE EXCEPTION OF A MOUNTING BRACKET ON THE B-PILLAR FOR THE WEB LOCKING MECHANISM, THE TORINOS WERE NOT MODIFIED IN ANY MANNER. THE MATRIX OF TEST CONDITIONS (IMPACT CONDITIONS AND RESTRAINT CONFIGURATIONS), AND DATA SUMMARY (DUMMY POSITION, RESTRAINT SYSTEM, HEAD (PEAK G, HIC (HEAD INJURY CRITERION)), CHEST (PEAK G, CSI (CHEST SEVERITY INDEX), AND VELOCITY CHANGE) ARE TABULATED. SUMMARIES OF VEHICLE DATA, INJURY CRITERIA, RESTRAINT SYSTEM DATA, AND OCCUPANT RESPONSE DATA ARE TABULATED FOR EACH OF THE NINE TESTS. VEHICLE ACCELEROMETER LOCATIONS AND COORDINATES ARE DENOTED FOR EACH TEST. PLOTTED DATA FROM EACH TEST ARE PRESENTED, AND PHOTOS SHOWING THE BEFORE AND AFTER CONDITIONS OF THE VEHICLES AND RESTRAINT SYSTEMS ARE PROVIDED. THE TESTS INVOLVED COLLISIONS WITH 1976 VOLVO 244'S.

R<DAT> 1977 R<AUT> FITZPATRICK, MICHAEL U. R<COR> FITZPATRICK ENGINEERING, 490 RANCHITU VISTA RD., SANTA BARBARA, CALIF. 93108
R<TTL> VEHICLE INTEGRATION AND EVALUATION OF ADVANCED RESTRAINT SYSTEMS - RESTRAINT SYSTEMS ANALYSES. FINAL REPORT
<FIL>DOTI 80H33430 R<SUP> REPT. FOR OCT 1977-FEB 1978. INCLUDES RESULTS OF CONTRACTS DOT-HS-5-01215 AND DOT-HS-4-00917. R<COL> 204P
R<AVA> NTIS R<ISS> 78-11 R<CON> DOT-HS-6-01307; NHTSA-8-0147
R<ABS> SLED TESTS AND VEHICLE CRASH TESTS WERE CONDUCTED IN ORDER TO EVALUATE THE PERFORMANCE OF FOUR ADVANCED RESTRAINT SYSTEMS IN A COMPACT SIZE AUTOMOBILE (1976 VOLVO 244). THE RESTRAINT SYSTEMS CHOSEN WERE: ADVANCED DRIVER AIRBAG SYSTEM; ADVANCED PASSENGER AIRBAG SYSTEM; FORCE-LIMITED AIRBELT SYSTEM; AND FORCE-LIMITED TWO-INCH BELT SYSTEM. USING FEDERAL MOTOR VEHICLE SAFETY STANDARD (FMVSS) 208 INJURY CRITERIA, THE RESTRAINT SYSTEMS' RANKING INDICATED A TIE BETWEEN THE AIRBELT AND RIGHT FRONT PASSENGER SYSTEM, FOLLOWED BY THE DRIVER AIRBAG AND THE FORCE-LIMITED TWO-INCH BELT SYSTEMS. ONLY THE FORCE-LIMITED TWO-INCH BELT FAILS TO MEET THE HEAD INJURY CRITERION (HIC) REQUIREMENT FOR THE FULL FRONTAL IMPACT MODE, WHICH IS THE ONLY MODE TO TEST THE SYSTEMS AT NEAR OR ABOVE CRITERIA LIMITS. THE SURVIVABILITY LIMIT FOR THE FIRST TWO SYSTEMS IS OVER 50 MPH, SHADING DOWN TO LESS THAN 48 MPH FOR THE LEAST EFFECTIVE SYSTEM. ALL SYSTEMS ARE "CHEST CRITICAL" FOR ALL IMPACT MODES, EXCEPT FOR THE FORCE-LIMITED TWO-INCH BELT SYSTEM, WHICH IS "HEAD CRITICAL" FOR THE FRONTAL MODE, AND "CHEST CRITICAL" FOR THE OFFSET AND OBLIQUE MODES. ALL FOUR SYSTEMS TESTED SHOWED A PERFORMANCE LEVEL FAR GREATER THAN FMVSS 208 REQUIREMENTS. IT IS RECOMMENDED THAT THESE SYSTEMS BE "PRODUCTIONIZED" AND RETESTED FOR EVENTUAL INSTALLATION IN PRODUCTION VEHICLES.

R<DAT> 1977 R<AUT> GATES, HOWARD P., JR.; GOLDMUNTZ, LAWRENCE R<CUR> ECONOMICS AND SCIENCE PLANNING, INC., 1200 18TH ST., N. W., SUITE 610, WASHINGTON, D. C. 20036 R<TTL> COMPARATIVE EFFECTIVENESS OF OCCUPANT RESTRAINT SYSTEMS

<FIL>DOTI 02H28160 R<COL> 31P 1REF R<AVA> CORPORATE AUTHOR R<ISS> 78-09 R<REF> DOC-74-14 R<ABS> THE SAFETY OF THREE TYPES OF OCCUPANT CRASH PROTECTION IN PASSENGER CARS IS COMPARED: PASSIVE RESTRAINTS, CONVENTIONAL HARNESSES, AND CRASH-ACTUATED HARNESSES. IN ADDITION, A LIMITED CRITIQUE IS MADE OF FIVE REPORTS ON LABORATORY STUDIES. THE COMPARISON OF RESTRAINT SYSTEMS FOCUSED ON FIELD TRIAL EXPERIENCE SINCE THIS IS THE MOST RELIABLE INDICATION OF PERFORMANCE; AS THERE IS NO FIELD EXPERIENCE WITH CRASH ACTUATED HARNESSES, A COMPARISON OF THIS SYSTEM WITH CONVENTIONAL AND PASSIVE HARNESSES MUST RELY ON LABORATORY TRIALS. BECAUSE OF THE DIFFERENT TEST PROTOCOLS OF THE VARIOUS STUDIES IT IS DIFFICULT TO OBTAIN A RELIABLE ESTIMATE OF THE RELATIVE PERFORMANCE OF DIFFERENT RESTRAINT SYSTEMS WHEN THEY ARE EVALUATED BY DIFFERENT LABORATORIES. DIFFICULTY IN SIMULATING CRASHES MAY RESULT IN ADEQUATE PERFORMANCE BY A RESTRAINT SYSTEM IN LABORATORY CRASHES BUT NOT IN REAL WORLD CRASHES. BECAUSE OF THE AIRBELT'S RAPID DEPLOYMENT TIME, ITS FORCE-LIMITED ANCHORS, AND THE FACT THAT THE INFLATED TORSO BELT SUPPORTS THE HEAD AND RESULTS IN MUCH LOWER BODY CONTACT PRESSURES THAN CONVENTIONAL BELT SYSTEMS, IT HAS THE POTENTIAL FOR THE LOWEST INJURY LEVELS OF ANY RESTRAINT SYSTEM. SEATBELT SYSTEMS OFFER AN EFFECTIVE AND LOW COST SAFETY SYSTEM; ADDITIONAL RESEARCH COULD DEVELOP OPTIMIZED SYSTEMS TO INCREASE PROTECTION AND COMFORT. MANDATED CRASH-ACTUATED, FORCE-LIMITED HARNESSES PROVIDE SAFETY BENEFITS WITH RESPECT TO MANDATED HARNESSES WHICH IN TURN ARE SAFER THAN MANDATED AIR BAGS.

R<DAT> 1977 R<AUT> HENDERSON, J. MICHAEL; VAZEY, BRIAN A.; HERBERT, DAVID C.; STOTT, JOHN D. R<COR> DEPARTMENT OF MOTOR TRANSPORT, TRAFFIC ACCIDENT RES. UNIT, BOX 28, G.P.O., SYDN R<TTL> THE EFFECT OF SEAT BELT DESIGN AND ANCHORAGE GEOMETRY ON INJURY PATTERNS AUSTRALIA

<FIL>DOTI 02H32820 R<CIT> HS-023 250, "INTERNATIONAL CONFERENCE OF THE INTERNATIONAL ASSOCIATION FOR ACCIDENT AND TRAFFIC MEDICINE (6TH) PROCEEDINGS," MELBOURNE, 1977 P407-22 R<COL> 7REFS R<AVA> IN HS-023 250 R<ISS> 78-11 R<ABS> THE EFFECT OF SEATBELT DESIGN AND ANCHORAGE GEOMETRY ON INJURY PATTERNS HAS BEEN EXAMINED AS PART OF A PROGRAM OF FIELD (AUSTRALIA) AND LABORATORY INVESTIGATIONS. INJURY INDUCED BY THE BELT ITSELF IS RARE. IT IS MOST COMMONLY SUFFERED IN THE ABDOMINAL REGION BY ELDERLY OCCUPANTS. FACTORS PREDISPOSING TO SUCH INJURY INCLUDE SLACKNESS OF ADJUSTMENT AND THE GEOMETRY OF THE INSTALLATION OF THE LAP PORTION OF THE SEAT BELT, INCLUDING ITS ANGLE FROM THE HORIZONTAL. RADIOGRAPHIC AND OTHER ANATOMICAL STUDIES HAVE SHOWN THAT THE PERMITTED MINIMUM ANGLE OF APPROACH OF THE LAP BELT SHOULD BE SUBSTANTIALLY INCREASED FROM THE PRESENT FIGURE OF 250 FROM THE HORIZONTAL, AND THAT MOUNTING THE LAP PORTION ON THE SEAT WOULD BE ADVANTAGEOUS. HEAD AND NECK INJURIES IN THE ABSENCE OF HEAD CONTACT ARE EXCEEDINGLY RARE. THE SASH PORTION OF THE LAP-SASH BELT IS RARELY THE SOURCE OF SEVERE INJURY. SEAT BELTS PERMIT SOME EXCURSION OF THE BODY IN CRASHES, AND THIS EXCURSION IS A COMMON CAUSE OF INJURY AMONG BELTED OCCUPANTS. LATERAL EXCURSION OCCURS IN CRASHES ONLY A FEW DEGREES AWAY FROM HEAD-ON; AND HEAD CONTACT, THE COMMONEST CAUSE OF DEATH AMONG SEAT-BELTED OCCUPANTS, COMMONLY OCCURS AGAINST PARTS OF THE VEHICLE NOT COVERED BY AUSTRALIAN DESIGN RULES. EMERGENCY LOCKING RETRACTORS INCREASE EXCURSION, BUT NOT TO A DANGEROUS EXTENT; AND EXCURSION COULD BE MINIMIZED BY THE USE OF PRE-TENSIONING DEVICES. RETRACTORS MANDATED BY AUSTRALIAN DESIGN RULES APPEAR TO WORK WELL IN THE FIELD. FINALLY, BELTED OCCUPANTS ARE MOST COMMONLY INJURED BY FACTORS NOT DIRECTLY RELATED TO SEATBELT DESIGN AND ANCHORAGE GEOMETRY, SUCH AS RIGIDITY OF CAR SIDE INTERIORS, INTRUSION OF THE CAR'S INTERIOR SURFACE, AND INTRUSION OF EXTRANEOUS OBJECTS.

R<DAT> 1977 R<AUT> HONTSCHIK, HEINRICH; MULLER, EGBERT; RUTER, GERT R<COR> BATTELLE-INSTITUT E.V., FRANKFURT AM MAIN, GERMANY R<TTL> NECESSITIES AND POSSIBILITIES OF IMPROVING THE PROTECTIVE EFFECT OF THREE-POINT SEAT BELTS

<FIL>DOTI 02H18000 R<CIT> HS-021 782 (SAE-P-73), "STAPP CAR CRASH CONFERENCE (21ST) PROCEEDINGS," WARRENDALE, PA., 1977 P793-831 R<SUP> PRESENTED AT THE CONFERENCE, NEW ORLEANS, 19-21 OCT 1977. INVESTIGATION CARRIED OUT FOR THE BUNDESANSTALT FUR STRASSENWESEN, COLOGNE, GERMANY. R<COL> 10REFS R<REP> SAE-770933 R<AVA> IN HS-021 782 R<ISS> 78-04 R<ABS> IN THE SECOND PHASE OF A RESEARCH PROGRAM COVERING MORE THAN 100 CATAPULT-SIMULATED FRONTAL COLLISIONS AT AN IMPACT SPEED OF 50 KM/H, INVESTIGATION WAS MADE OF THE POSSIBILITY OF IMPROVING THE PROTECTIVE EFFECT OF THE SAFETY BELT, EITHER BY AN INTEGRATED SEAT BELT SYSTEM, A PYROTECHNIC PRELOAD DEVICE, OR HYDRAULIC LOAD-LIMITING ELEMENTS. WITH THE THREE-POINT SEAT BELT SYSTEMS, STUDIES WERE MADE OF THE EFFECT OF VARYING LOCATIONS OF THE ANCHORAGE POINTS, THE INFLUENCE OF BODY SIZE, SEAT ADJUSTMENT, AND SEATING POSITION, THE INFLUENCE OF SEAT STIFFNESS AND BELT SLACK. INTEGRATED SEAT BELT SYSTEMS ARE RECOMMENDED, IN WHICH ALL ELEMENTS OF THE RESTRAINT SYSTEM ARE FIXED TO THE SEAT. OPTIMUM BELT DESIGN CAN BE ACHIEVED NOT ONLY FOR PERSONS OF AVERAGE SIZE AND WEIGHT, BUT ALSO FOR THOSE OF PARTICULARLY SMALL SIZE AND LOW WEIGHT AS WELL AS FOR TALL AND HEAVY PERSONS.

R<DAT> 1977 R<AUT> SCHMIDT, G.; KALLIERIS, D.; KAPPNER, R.; MATTERN, R.; SCHULZ, F. R<COR> UNIVERSITY OF HEIDELBERG, INST. OF LEGAL MEDICINE, HEIDELBERG, GERMANY R<TTL> FORENSIC PATHOLOGICAL AND BIOMECHANICAL EXPERIENCES AFTER THE FIRST YEAR OF MANDATORY BELT WEARING IN THE FEDERAL REPUBLIC OF GERMANY SEAT BELTS

<FIL>DOTI 02H32800 R<CIT> HS-023 250, "INTERNATIONAL CONFERENCE OF THE INTERNATIONAL ASSOCIATION FOR ACCIDENT AND TRAFFIC MEDICINE (6TH) PROCEEDINGS," MELBOURNE, 1977 P365-91 R<SUP> SPONSORED IN PART BY VERBAND DER AUTOMOBIL-INDUSTRIE E.V., WEST GERMANY. R<AVA> IN HS-023 250 R<ISS> 78-11 R<ABS> THE EFFECT OF MANDATORY SEATBELT USAGE LEGISLATION IN THE FEDERAL REPUBLIC OF GERMANY (FRG), WHICH WENT INTO EFFECT ON 1 JAN 1976, ON TRAFFIC INJURIES/FATALITIES IS DISCUSSED, AS WELL AS LITERATURE ON THE EFFECTIVENESS OF SEAT BELTS IN PREVENTING INJURIES. IN THE FRG, 87% OF THE CARS ARE EQUIPPED WITH SAFETY BELTS, AND BELTS ARE USED IN NEARLY TWO THIRDS OF THE CARS IN WHICH THEY ARE INSTALLED. ABOUT 75% OF THE DRIVERS USE BELTS ON THE AUTOBAHN AND ON HIGHWAYS AND 54% IN TOWNS. TO DATE, EXPERIENCE IN BADEN-WURTTEMBERG INDICATES NO DECREASE IN THE NUMBER OF INJURED DRIVERS AS A RESULT OF THE LEGISLATION; HOWEVER, THERE HAS BEEN A DECREASE OF ABOUT 10% IN THE NUMBER OF PERSONS KILLED IN TRAFFIC ACCIDENTS (I.E. ALL VEHICLE OCCUPANTS AND PEDESTRIANS). HOWEVER, IT MUST BE REALIZED THAT ALTHOUGH THE DECREASE WAS RELATIVELY SMALL, A REDUCTION WAS ACHIEVED IN SPITE OF THE INCREASE IN THE NUMBER OF MOTOR VEHICLES (5.2%) AND TOTAL MILEAGE (4.7%). RESEARCH IS CITED WHICH SHOWS THE EFFECTIVENESS OF SEAT BELTS IN AFFORDING PROTECTION TO VEHICLE OCCUPANTS, THE SIGNIFICANCE OF AGE IN THE FREQUENCY AND SEVERITY OF INJURIES, AND THE HIGHER NUMBER OF NECK AND BACK INJURIES SUFFERED BY BELT USERS (ALTHOUGH SELDOM SEVERE). FURTHER DEVELOPMENT (BELT FORCE LIMITERS, PRELOADING, COMBINATIONS WITH THE AIR BAG, STANDARDIZED PARTS, AND PASSIVE SYSTEMS) OF CURRENTLY AVAILABLE RESTRAINT SYSTEMS, INFORMING AND INFLUENCING THE PUBLIC REGARDING THE PROTECTION OFFERED BY SEAT BELTS, INCENTIVES TO SEAT BELT USERS BY INSURANCE COMPANIES, AND INFORMING PHYSICIANS IF ACCIDENT VICTIMS HAVE WORN SAFETY BELTS, ARE ADVOCATED.

R<DAT> 1976 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221(R<TTL> RESEARCH SAFETY VEHICLE (RSV) CRASH TEST REPORT. RSV TEST NO. 5. 45 MPH FLAT BARRIER FRONTAL IMPACT(
<FIL>DOTI 80H21980 R<COL> 59P R<AVA> REFERENCE COPY ONLY R<ISS> 77-06 R<CON> DOT-HS-5-01214 R<ABS> CRASH TESTING WAS MADE OF A RESEARCH SAFETY VEHICLE (RSV) FRONTALLY INTO A FLAT BARRIER AT AN IMPACT SPEED OF 45 MPH. DUMMIES (HYBRID II PART 572) WERE PLACED IN THE LEFT-FRONT AND RIGHT-FRONT SEATING POSITIONS. THE TEST VEHICLE WAS A MODIFIED SIMCA 1308 (BASE VEHICLE) WHERE ALL IMPORTANT RSV STRUCTURAL ELEMENTS WERE INCORPORATED INTO THE DESIGN. THE FRONT SEAT OCCUPANT PROTECTION SYSTEM INCLUDED SHOULDER AIR BELTS WITH LOAD LIMITERS, LAP BELTS WITH LOAD LIMITERS, SHEET METAL KNEE RESTRAINT (I.P.), T-SLOTTED BREAKAWAY STEERING LINKAGE, AND REWORKED FRONT SEAT CUSHIONS, SEAT BACK STRUCTURE AND TRACKS. REASONABLY GOOD PASSENGER COMPARTMENT INTEGRITY WAS EXHIBITED. THE MAXIMUM FIREWALL INTRUSION WAS 14.2 INCHES. NEVERTHELESS, REARWARD MOVEMENT OF THE KNEE RESTRAINT (I.P.) WAS LIMITED TO ABOUT THREE INCHES. PASSENGER COMPARTMENT LONGITUDINAL ACCELERATIONS AND VEHICLE CRUSH WERE NOMINALLY CONSISTENT WITH PREVIOUS COMPUTER SIMULATIONS. HOWEVER, PERFORMANCE CHARACTERISTICS OF THE DUMMIES, NOTABLY HEAD ACCELERATIONS, WERE UNACCEPTABLE. IT IS SUGGESTED THAT CERTAIN CHANGES IN BOTH THE VEHICLE STRUCTURAL AND RESTRAINT SYSTEM PERFORMANCE WILL BE NECESSARY BEFORE ACCEPTABLE DUMMY PERFORMANCE IS ACHIEVED. SPECIFICALLY, SUBSTANTIAL VEHICLE PITCH TOOK PLACE. THIS RESULTED IN THE DUMMIES BEING LOADED IN A SOMEWHAT DIFFERENT MANNER THAN WAS THE CASE WITH SLED TESTING. THUS, A CHANGE IN THE DESIGN TO REDUCE VEHICLE PITCH IS ESSENTIAL. PREVIOUS RESTRAINT SYSTEM DEVELOPMENT WAS BASED UPON RESTRICTING DYNAMIC STEERING COLUMN MOVEMENT (IN THE DIRECTION OF THE COLUMN) TO NOT MORE THAN THREE INCHES. IN THIS TEST, STATIC WHEEL/HUB DISPLACEMENTS ON THE ORDER OF SIX INCHES WERE OBSERVED. SOME REDESIGN TO REDUCE STEERING SYSTEM INTRUSION IS NECESSARY. IN ADDITION, SUBSEQUENT TO THE TEST, IT WAS LEARNED THAT THE OUTBOARD LAP BELT ANCHOR POINTS WERE INCORRECTLY LOCATED NEAR THE FLOORPAN SILL INSTEAD OF IN A DOOR ATTACHMENT ORIENTATION. THESE ANCHOR POINTS WERE, THEREFORE, TOO LOW, WHICH CONTRIBUTED TO THE ADVERSE DUMMY KINEMATICS AS A RESULT OF EXCESSIVE DOWNWARD LOADING. FINALLY, DUMMY REBOUND INTO THE B-PILLARS MUST BE CONSIDERED. THE PROBLEM HERE GENERALLY RELATES TO PROVIDING MORE BAG VENTING (HIGHER BAG POROSITY), BETTER LOAD LIMITER PERFORMANCE (LOAD LIMITER PERFORMANCE IS DIRECTLY RELATED TO VEHICLE PITCH), AND PROVIDING SOME IMPACT PROTECTION ON THE B-PILLAR. THE EFFECT OF FIXED VS. BREAKAWAY D-RINGS MUST ALSO BE REEXAMINED. THE PROBLEMS NOTED ABOVE CAN BE CORRECTED IN A STRAIGHTFORWARD MANNER.

R<DAT> 1976 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221(R<TTL> RESEARCH SAFETY VEHICLE (RSV) CRASH TEST REPORT. TEST: MOD. B (MODIFIED BASELINE VEHICLE). TYPE OF TEST: BARRIER CRASHES (NO DAMAGE - 5 MPH FOLLOWED BY 35 MPH)

<FIL>DOTI 80H21260 R<COL> 59P R<AVA> REFERENCE COPY ONLY R<ISS> 77-04 R<CON> DOT-HS-5-01214 R<ABS> TWO FLAT BARRIER IMPACT TESTS WERE PERFORMED ON A MODIFIED RESEARCH SAFETY VEHICLE (RSV) (SIMCA 1307), ONE AT 5 MPH, THE OTHER AT 35 MPH. THE RSV FRONT WAS ALTERED TO ACCEPT A SOFT FRONT BUMPER SYSTEM TO WHICH THREE SENSORS WERE ATTACHED. THESE WERE TO BE TESTED FOR ACTUATION DURING THE 5 MPH IMPACT. INTERIOR ALTERATIONS INCLUDED THE INSTALLATION OF RSV DEVELOPED AIRBELTS AND LOAD LIMITERS, CONVENTIONAL RETRACTORS, A SHEET METAL KNEE BOLSTER, AND A T SLOTTED BREAKAWAY STEERING LINKAGE, ALL OF WHICH WERE TO BE OBSERVED AFTER THE 35 MPH IMPACT. THREE SENSORS, ONE OF WHICH ACTUATED THE PRESSURE BOTTLE THAT INFLATED THE AIRBELTS, WERE MOUNTED IN SEPARATE LOCATIONS TO BE MONITORED FOR PERFORMANCE AS A FUNCTION OF LOCATION DURING THE 35 MPH IMPACT. TWO FEET OF BELT WEBBING WERE LEFT SPOOLED ON THE PASSENGER BELT RETRACTOR AND ONLY ONE INCH ON THE DRIVER SIDE TO PROVIDE AN ESTIMATE OF THE ADDITIONAL SLACK INTRODUCED BY THE AMOUNT OF REMAINING BELT SPOOLED AROUND THE RETRACTOR DURING THE 35 MPH IMPACT. OCCUPANT DUMMIES WERE PLACED IN DRIVER AND FRONT PASSENGER POSITIONS. IN THE 5 MPH TEST, NO VISIBLE VEHICLE DAMAGE WAS APPARENT, AND THE BUMPER IMPULSE DETECTORS DID NOT FIRE. COMPARISON OF THE BUMPER FORCE-DEFLECTION CHARACTERISTIC WITH PREVIOUSLY PERFORMED PENDULUM-BARRIER TESTS WAS NOT ACHIEVED. IN THE 35 MPH IMPACT TEST, THE RESULTS WERE FOUND SATISFACTORY. ALL THREE SENSORS DEPLOYED. THE BREAKAWAY STEERING LINKAGE FUNCTIONED PROPERLY. THE SHEET METAL KNEE BOLSTER PERFORMANCE WAS ACCEPTABLE AND MORE CRUSH COULD HAVE BEEN ACCOMMODATED. FOR OCCUPANTS, ALL HEAD AND CHEST INJURY INDICATORS WERE REDUCED, PARTICULARLY HEAD PEAK G'S. FINALLY, ONLY A VERY LIMITED ESTIMATE OF THE ADDITIONAL SLACK INTRODUCED BY BELT WEBBING SPOOLED AROUND THE RETRACTOR WAS ATTAINED. BOTH VEHICLE AND DUMMY ELECTRONIC DATA ARE DISPLAYED.

R<DAT> 1976 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221 R<TTL> RESEARCH SAFETY VEHICLE (RSV) PHASE 2. STATUS REPORT NO. 4, 16 JANUARY TO 15 MARCH 1976

<FIL>DOTI 80H18570 R<COL> 32P R<REP> PR-4 R<AVA> REFERENCE COPY ONLY R<ISS> 76-08 R<CON> DOT-HS-5-01214 R<ABS> WORK CONDUCTED ON THE DEVELOPMENT OF A RESEARCH SAFETY VEHICLE (RSV) BY THE CALSPAN CORPORATION DURING THE PERIOD 16 JANUARY THROUGH 15 MARCH 1976 IS REPORTED. DEVELOPMENTAL ENGINEERING EFFORTS DURING THIS PERIOD WERE FOCUSSED ON THE DESIGN OF THE STRUCTURES, BUMPERS, AND RESTRAINT SYSTEMS. A CAR-TO-CAR COMPATIBILITY STUDY WAS CONDUCTED USING THE CALSPAN VEHICLE COLLISION MODEL TO SIMULATE FRONT-TO-FRONT, FRONT-TO-SIDE, AND FRONT-TO-REAR COLLISION SITUATIONS. A PEDESTRIAN/BUMPER IMPACT SIMULATION STUDY FOCUSSED ON THE EFFECTS OF BRAKING AND PITCHING OF THE IMPACTING VEHICLE. DEVELOPMENTAL WORK ON THE DOOR INNER ENERGY ABSORBING PANEL WAS CONFINED MOSTLY TO EXPLORATION OF THE POTENTIAL USEFULNESS OF CERTAIN SIMULATION MODELS. THE VEHICLE STRUCTURAL SIMULATION MODEL WAS EXPANDED TO INCLUDE THE INTERACTION BETWEEN DUMMY TORSO AND THE VEHICLE SIDEWALL MASSES. A PASSIVE AIRBELT RESTRAINT SYSTEM WAS MOCKED UP IN ONE OF THE BASE VEHICLES. POTENTIAL PACKING PROBLEMS WERE IDENTIFIED. EFFORTS CONTINUED WITH THE DEVELOPMENT OF THE INFLATABLE BELT RESTRAINT SYSTEM WITH LIMITED EFFORT ALSO DIRECTED TOWARD THE DEVELOPMENT OF PRELIMINARY DESIGN CONCEPTS FOR BOTH THE KNEE BAR AND LOAD LIMITERS. MODEST EFFORT ALSO CONTINUED USING THE 3-D CRASH VICTIM MODEL TO SIMULATE VARIOUS FRONTAL COLLISION EXPOSURES. A VARIETY OF TESTING ACTIVITIES IN SUPPORT OF THE BUMPER, STRUCTURAL, AND RESTRAINT SYSTEM DESIGN EFFORTS WERE PERFORMED: BODY BLOCK TESTS WITH A FOAM RUBBER SAMPLE CUT TO RESEMBLE THE OUTERMOST TWO FEET OF THE RSV; A CRUSH TEST ON THE FRONT RAILS OF THE BASE VEHICLE USING A POLE OBSTACLE RAM FACE; STATIC LOADING DETERMINATION OF THE LATERAL TORSO COMPLIANCE PROPERTIES OF A PART 572 DUMMY; SLED TESTS FOR RESTRAINT DEVELOPMENT AND SUPPORT; DEVELOPMENT OF A BODY BUCK FOR THE NEXT SERIES OF SLED TESTING; AND BRAKING AND FUEL ECONOMY TESTING FOR THE BASE VEHICLE.

R<DAT> 1976 R<COR> CALSPAN CORP., BUFFALO, N.Y. 14221 R<TTL> RESEARCH SAFETY VEHICLES (RSV). PHASE 2. THIRD STATUS REPORT <FIL>DOTI 80H18150 R<SUP> REPORT FOR 16 NOV 1975-15 JAN 1976. R<COL> 133P R<REP> ZM-5793-V R<AVA> REFERENCE COPY ONLY R<ISS> 76-07 R<CON> DOT-HS-5-01214 R<ABS> THE DEVELOPMENT OF A RESEARCH SAFETY VEHICLE (RSV) BY CALSPAN CORPORATION IS DISCUSSED. KEY TECHNICAL DECISIONS WITH REGARD TO THE RSV FRONT STRUCTURE FORCE-DEFLECTION CHARACTERISTICS AND THE FRONT SEAT OCCUPANT RESTRAINT SYSTEMS WERE MADE DURING THIS REPORTING PERIOD. BUMPER PEDESTRIAN IMPACT SIMULATIONS WERE CONDUCTED USING BOTH ADULT AND CHILD MODELS. EXTENSIVE FRONT-TO-SIDE VEHICLE-TO-VEHICLE IMPACT SIMULATIONS WERE PERFORMED TO AID IN THE DESIGN OF THE FRONT STRUCTURAL FORCE-DEFLECTION CHARACTERISTICS. EFFORTS WERE BEGUN TO CONSIDER OCCUPANT RESPONSES IN THE VEHICLE-TO-VEHICLE IMPACT MODEL. EFFORT WAS INITIATED ON THE DEVELOPMENT OF AN ENERGY ABSORBING DOOR INNER PANEL. AIR BAG COMPUTER SIMULATIONS WERE PERFORMED AND A PRELIMINARY PASSENGER SIDE DESIGN WAS DEVELOPED. AIR BAG ANALYTICAL RESULTS WERE COMPARED WITH THOSE DEVELOPED FROM SLED TESTS. ALTHOUGH THE SIMULATIONS TEND TO CORRECTLY PREDICT LIMITING ACCELERATION VALUES, THEY ALSO TEND TO PREDICT SOMEWHAT EARLIER OCCUPANT LOADINGS THAN WERE EVIDENT IN THE TESTS. BELT SYSTEMS SIMULATIONS WERE CONTINUED AND A PRELIMINARY DESIGN DEVELOPED. BELT SYSTEM COMPUTER SIMULATIONS WERE COMPARED TO TEST DATA AND IN GENERAL THE SIMULATION RESULTS ARE VIEWED AS A REASONABLE INDICATION OF EXPECTED PERFORMANCE. HOWEVER, THE SIMULATIONS TEND TO PREDICT LARGER KNEE BAR PENETRATION THAN THAT WHICH WAS OBSERVED IN THE TESTS. THE CANDIDATE BUMPER FOAM MATERIAL WAS SUBJECTED TO AN EXTENSIVE SERIES OF BODY BLOCK, FLAT BARRIER, AND VEHICLE IMPACT TESTS.

R<DAT> 1976 R<AUT> BEZ, ULRICH R<COR> PORSCHE RES. AND DEVEL. CENTRE, FEDERAL REPUBLIC OF GERMANY(R<TTL> INFLUENCE OF THE SHAPE OF THIN-WALL STRUCTURES AND STRUCTURAL ELEMENTS ON THE DYNAMIC BEHAVIOUR OF THE OVERALL PASSENGER-VEHICLE SYSTEM DURING IMPACTS(

<FIL>DOT! 01H95690 R<SUP> PRESENTED AT SIXTH INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES, WASHINGTON, D.C., 12-16 OCT 1976. PROCEEDINGS TO BE PUBLISHED APR 1977. R<COL> 27P 29REFS R<AVA> CORPORATE AUTHOR R<ISS> 77-03 R<ABS> DURING THE COLLISION OF THE VEHICLE WITH AN OBSTACLE, SHOCK-LIKE IMPACT FORCES ARE ACTING UPON THE PASSENGERS. THIS SHOCK-LIKE LOAD CAN BE CONSIDERED AS A TRANSIENT OSCILLATION PROCESS. A CORRESPONDING ANALYSIS, EFFECTED AT ANY DEFINED POINT OF THE CAR, REVEALS THAT THE BASIC FREQUENCY IS SUPERIMPOSED BY FREQUENCY SPECTRA OF DIFFERING DENSITY AND DIRECTION. THE PASSENGER'S BODY ALSO CONSTITUTES AN OSCILLATORY ELEMENT, WHICH IS REPRESENTED BY MUSCLES AND BONES ON ONE HAND, AND THE EMBEDDED ORGANS AND LIQUIDS WITH THEIR RESPECTIVE COUPLINGS ON THE OTHER. MATHEMATICAL SIMULATORY MODELS FOR SOME SUBDOMAINS ARE KNOWN FROM PERTINENT LITERATURE. THE FREQUENCY SPECTRUM IS CREATED DURING THE VEHICLE DEFORMATION PHASE AND TRANSMITTED TO THE PASSENGER THROUGH THE STRUCTURAL ELEMENTS, THE SEAT BELT ANCHORAGE POINTS, OR OTHER VEHICLE PARTS. FROM OTHER RESEARCH SECTORS IT IS KNOWN THAT WITH OSCILLATORY STRESSES, CERTAIN FREQUENCY RANGES ARE SPECIALLY HARMFUL TO MAN. SPECIFICALLY, FOR THE THORAX AND ABDOMEN SYSTEM THE CRITICAL RANGES ARE GENERALLY INFERIOR TO TEN CYCLES PER SECOND (CPS), WHEREAS FOR THE SKULL AND BRAIN MORE EXTENSIVE CRITICAL FREQUENCIES INCLUDING 3-10, 20-30 AND OVER 100 CPS HAVE BEEN REPORTED. IT MUST THEREFORE BE ASSUMED THAT ALSO IN THE CASE OF SHOCKLIKE IMPACT FORCES ACTING UPON THE PASSENGER, THERE ARE SOME FREQUENCY RANGES WHICH HAVE NOXIOUS EFFECTS ON VITAL FUNCTIONS OF THE HUMAN BODY. BEFORE CLOSELY INVESTIGATING THESE RANGES, IT HAS TO BE FOUND OUT WHETHER IT IS POSSIBLE AT ALL TO INFLUENCE FREQUENCY RANGES BY CORRESPONDING DESIGN OF THE OVERALL STRUCTURES AND OF THE STRUCTURAL ELEMENT. THEREFORE, AN ANALYSIS OF TYPICAL REALISTIC THIN-WALL STRUCTURES TO BE USED IN VEHICLE DEFORMATION ZONES WAS DONE. USING TUBE, OVAL AND BOX-TYPE STRUCTURES, TESTS SHOW THAT THE OCCURRING FREQUENCY RANGES MAY BE INFLUENCED. HOWEVER, SINCE THE SHOCK FREQUENCY IS ESSENTIALLY INFLUENCED BY THE CRASH CONDITIONS, IT SEEMS TO BE DOUBTFUL WHETHER IT WILL BE POSSIBLE TO SUFFICIENTLY INFLUENCE ALL FREQUENCY RANGES BY SIMPLY MODIFYING AT THE BODY STRUCTURE DESIGN. IT APPEARS MORE REALISTIC TO SHIFT FROM RANGES INFERIOR TO 150 CPS TO SUPERIOR ONES OR VICE VERSA. THE RANGE INFERIOR TO TEN CPS CAN ONLY BE TENDENTIALLY INFLUENCED. IT IS ALSO SUGGESTED THAT VEHICLES PROVIDE ONE OR MORE FILTER ELEMENTS BETWEEN THE PASSENGER AND THE VEHICLE, WHICH, REGARDLESS OF THE INPUT, KEEP DANGEROUS FREQUENCIES AWAY FROM MAN. HOWEVER, IT WILL BE ALMOST IMPOSSIBLE TO SUBSTANTIALLY INFLUENCE THE BASIC FREQUENCY OR TO SHIFT IT TO RANGES OF 20 CPS AND MORE, AS THERE ARE ONLY LIMITED PATHS AVAILABLE AS CONCERNS BOTH THE VEHICLE STRUCTURE AND THE VEHICLE INTERIOR.

R<DAT> 1976 R<AUT> BRAESS, H.-H. R<TTL> SEAT MOVEMENT RELATIVE TO THE PASSENGER COMPARTMENT--A POSSIBLE METHOD TO IMPROVE PASSENGER PROTECTION DURING FRONTAL IMPACTS

<FIL>DOTI 02H33960 R<CIT> VEHICLE SYSTEM DYNAMICS V5 N3 P127-45 (OCT 1976) R<COL> 14REFS R<AVA> SEE PUBLICATION R<ISS> 78-12 R<ABS> IT IS THEORETICALLY DEMONSTRATED THAT A CONTROLLED SEAT MOVEMENT RELATIVE TO THE PASSENGER COMPARTMENT WILL RESULT IN AN IMPROVEMENT OF PASSENGER DECELERATION DURING VEHICLE FRONTAL IMPACTS. AN ADJUSTING DEVICE WILL RELEASE A RELATIVE MOVEMENT OF THE SEAT AND THE RESTRAINED PASSENGER, ACTING AGAINST DRIVING DIRECTION, WHEN THE DECELERATION OF THE PASSENGER COMPARTMENT IS INFERIOR TO A CERTAIN MEAN DECELERATION DURING THE TOTAL DURATION OF CRASH. THIS COUNTERMOVEMENT SHALL CAUSE THE TOLERABLE HIGH DECELERATION OF THE OCCUPANT IN THE FIRST PHASE OF THE CRASH. THE RESULTING "GAINED" DISTANCE IN THE CAR SHALL BE USED TO REDUCE EXCEEDING VEHICLE DECELERATION BY A RELATIVE FORWARD MOVEMENT OF THE SEAT IN THE SECOND PHASE. IN ORDER TO ASSURE THE PRECISE FUNCTIONING, THE ACTUAL DECELERATION OF THE OCCUPANT COMPARTMENT HAS TO BE TRANSFORMED BY THE CONTROL UNIT INTO A SIGNAL RELEASING THE SERVO VALVE WHICH FURNISHES THE NECESSARY PRESSURE TO THE ADJUSTING CYLINDER. THE ENERGY REQUIRED CAN BE TAKEN FROM SPECIALLY MODIFIED IMPACT ABSORBERS. TO ACHIEVE THE DESIRED EFFECT, IT IS NECESSARY THAT THE OCCUPANT BE RESTRAINED RELATIVELY STIFFLY IN THE SEAT. THIS CAN BE ASSURED, FOR INSTANCE, BY A BELT SYSTEM WITH A PRELOADING DEVICE, I.E. AN ADDITIONAL SUBSYSTEM WHICH COULD BE INTEGRATED INTO THE TOTAL ADJUSTING SYSTEM. AT PRESENT ONLY THE FIRST STEP TOWARD THE FINAL SOLUTION OF THE PROBLEM HAS BEEN TAKEN. THE NEXT STEP MUST BE THE IMPROVEMENT OF THE SYSTEM BEHAVIOR IN THE CASE OF FRONTAL CRASHES, ESPECIALLY OF THE FREQUENCY CURVES OF THE FILTER AND OF THE ADJUSTMENT MECHANISM. THE SAME APPLIES TO THE ADAPTATION TO ALL POSSIBLE CRASH SITUATIONS IN CONNECTION WITH THE RESTRAINT SYSTEM, WHICH HAS NOT YET BEEN TREATED. THE PROPOSED EFFECT COULD BE ADVANTAGEOUS AS A POSSIBLE ALTERNATIVE FOR THE MOST FAVORABLE DESIGN OF THE ENERGY-ABSORBING ZONES OF A VEHICLE, AS AN ADDITIONAL SAFETY DEVICE FOR THE OCCUPANTS OF HEAVY VEHICLES WITH RELATIVELY SOFT IMPACT-ABSORBING ZONES IN CASE OF CRASHES AGAINST RIGID OBSTACLES, AND IN SMALL VEHICLES WITH REDUCED INTERIOR SPACE AND CONSEQUENTLY MORE FREQUENT PASSENGER IMPACTS TO THE COMPARTMENT INTERIOR.

R<DAT> 1976 R<AUT> DESBOIS, JACQUES A. R<COR> CENTRE D'ETUDES DE PARIS DES AUTOMOBILES PEUGEOT, BP16, 92250 LA GARENNE, FRANCE R<TTL> STATUS REPORT TRAFFIC SAFETY, PEUGEOT-
<FIL>DOTI 01H95980 R<SUP> PRESENTED AT THE SIXTH INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES, WASHINGTON, D.C., 12-16 OCT 1976. PROCEEDINGS TO BE PUBLISHED APR 1977. R<COL> 8P R<AVA> CORPORATE AUTHOR R<ISS> 77-03 R<ABS> FROM THE STANDPOINT OF THE MOST IMPORTANT ASPECTS OF STUDY WITH REGARD TO TRAFFIC SAFETY, PEUGEOT PRESENTS TRENDS AND RESULTS OF EXPERIMENTAL STUDIES ON FRONTAL IMPACT, SIDE IMPACT, AND PEDESTRIAN PROTECTION. WITH RESPECT TO FRONTAL IMPACT COLLISIONS AND THE WEARING OF SEAT BELTS, STUDIES HAVE INCLUDED INVESTIGATION OF FRONT STRUCTURES WHOSE DEFORMATION LAWS IN THE VARIOUS TYPES OF FRONTAL IMPACT PROVIDE AN OPTIMUM PROTECTION LEVEL FOR BELTED OCCUPANTS; STUDY OF THE INFLUENCE EXERTED BY BELT CHARACTERISTICS UPON THE PROTECTION LEVEL (RIGIDITY, INITIAL PLAY, ANCHORAGE GEOMETRY); IMPROVEMENT OF BELT COMFORT; DETERMINATION OF ACCIDENT ACTUAL SEVERITY BASED ON SPEED VARIATION AND VEHICLE MEAN DECELERATION AND SELECTION OF THE FRONTAL IMPACT TEST PROCEDURE; PARTICIPATION IN THE FOUNDATION OF A NATIONAL PHOTO LIBRARY WHOSE UTILIZATION SHOULD PERMIT ESTIMATING ACCIDENT FORCE; AND BIOMECHANICAL RESEARCH, ESPECIALLY AS CONCERNS HEAD AND THORAX TOLERANCES. WITH RESPECT TO LATERAL IMPACT COLLISIONS, A SAMPLE OF DATA ON LATERAL COLLISIONS WHICH HAS BEEN GATHERED IS BIG ENOUGH TO PERMIT EVALUATING CORRECTLY THE ACTUAL IMPACT CONDITIONS AS WELL AS THEIR SEVERITY; FOR BIOMECHANICAL RESEARCH, THE HEAD-NECK SEGMENT OF CURRENTLY PROPOSED DUMMIES IS IN NO WAY ADAPTED TO THE LATERAL IMPACT CONFIGURATION; AND A COMPROMISE BETWEEN THE LEVEL OF REDUCTION ACHIEVED FOR OCCUPANT COMPARTMENT INTRUSION AND THE LEVEL OF PROTECTION PROVIDED FOR INTERIOR WALLS IS BEING INVESTIGATED. AS FAR AS REGULATIONS IN THE AREA OF LATERAL IMPACT, IT IS SUGGESTED THAT IN THE SHORT RUN, THERE SHOULD BE AN IMPROVEMENT IN THE RESISTANCE TO INTRUSION ON CAR SIDES; IN THE MEDIUM RUN, THE SPECIFIC AGGRESSIVENESS OF ANY NEW CAR SHOULD BE LIMITED; AND IN THE LONG RUN, A DEFORMABLE MOVING BARRIER MAY BE SUBSTITUTED FOR A VEHICLE TO ACT AS AN OBSTACLE IN STUDIES. WITH RESPECT TO PEDESTRIAN PROTECTION, INVESTIGATIONS HAVE SHOWN THAT THE MOST SEVERE INJURIES ARE CAUSED BY THE IMPACT OF THE HEAD ON THE VEHICLE AND INJURIES BROUGHT ABOUT BY THE SECOND IMPACT AGAINST THE GROUND APPEAR LESS SEVERE THAN PREVIOUSLY SUPPOSED. THEREFORE, PRIORITY HAS BEEN GIVEN TO THE STUDY OF THE POSSIBLE IMPROVEMENTS IN THE DASHBOARD AREA AND THE IMPLANTATION OF THE WINDSHIELD FRAME. IT HAS ALSO BEEN SHOWN THAT THE BUMPER HAS NO PREPONDERANT INFLUENCE ON THE SEVERE OR FATAL INJURIES OF IMPACTED PEDESTRIANS.

R<DAT> 1976 R<AUT> EPPINGER, ROLF H. R<COR> NATIONAL HWY. TRAFFIC SAFETY ADMINISTRATION R<TTL> PREDICTION OF THORACIC INJURY USING MEASURABLE EXPERIMENTAL PARAMETERS
<FIL>DOTI 02H16470 R<CUL> 23P 13REFS R<AVA> REFERENCE COPY ONLY R<ISS> 78-03 R<ABS> AN EFFORT WAS MADE TO DERIVE AND EVALUATE A SIMPLE, NONEQUIVOCAL MEASURE WHICH CAN READILY ASSESS THE CRASH PROTECTIVE QUALITIES OF A CANDIDATE SEAT BELT SYSTEM, PROVIDE A SIMPLE, JUSTIFIABLE DYNAMIC TEST CRITERION FOR PROTECTION STANDARDS GENERATION, AND PROVIDE BOTH MANUFACTURERS AND STANDARDS MONITORS AN INEXPENSIVE, VALID METHOD OF DETERMINATION OF COMPLIANCE OF SYSTEM WITH THE MANDATED PERFORMANCE REQUIREMENTS. ANALYSIS IS MADE OF THE DATA OBTAINED FROM OVER 100 SIMULATED CAR CRASHES IN WHICH CADAVERS WERE RESTRAINED BY VARIOUS TYPES OF SAFETYBELT SYSTEMS. ALL PRESENTLY AVAILABLE CADAVER TEST DATA HAVE BEEN COLLATED AND ANALYZED STATISTICALLY TO DETERMINE IF ANY MEANINGFUL RELATIONSHIPS EXIST BETWEEN ANY OF THE MEASURED ENGINEERING PARAMETERS, SUCH AS FORCES, ACCELERATIONS, DEFLECTIONS, AND THE PHYSIOLOGICAL CONSEQUENCES (INJURY) OF EACH TEST EVENT. LARGE VARIATIONS IN TEST INSTRUMENTATION, TEST CONDITIONS, AND BELT SYSTEM CONFIGURATIONS UTILIZED BY THE VARIOUS RESEARCHERS LIMITED THE ANALYSIS TO THOSE MEASURED ENGINEERING PARAMETERS AND OBSERVED INJURY EVALUATIONS WHICH WERE COMMON TO ALL THE EXPERIMENTS. THIS VERY MINIMAL SET OF EVENT DESCRIPTORS, WHEN SUBJECTED TO ANALYSIS, HAS SHOWN INJURY, DEFINED IN THIS CONTEXT AS THE NUMBER OF OBSERVED THORACIC FRACTURES, TO BE A STATISTICAL FUNCTION OF THE MAXIMUM UPPER TORSO BELT FORCE, CADAVER WEIGHT, AND CADAVER AGE AT DEATH. THE ESSENTIAL ENGINEERING PARAMETER NECESSARY TO CORRELATE THE PERFORMANCE OF A BELT SYSTEM TO THORACIC INJURY IS THE EASILY MEASURED UPPER TORSO BELT FORCE. IT IS RECOMMENDED THAT, SINCE INJURY WAS DEFINED FOR THE PURPOSE OF THE STUDY AS THE NUMBER OF THORACIC FRACTURES, AN ANALYSIS OF THE SAME DATA SHOULD BE PERFORMED WHEN INJURY ASSESSMENTS IN TERMS OF ABBREVIATED INJURY SCALE BECOME AVAILABLE; THIS WOULD PREVENT OMISSION FROM THE TOTAL INJURY ASSESSMENT OF THE LIFE-THREATENING INJURIES TO INTERNAL ORGANS IN THE YOUNG POPULATION WHERE SKELETAL DAMAGE IS NOT SO PREVALENT. RESEARCH WITH CADAVERS SHOULD CONTINUE; SUCH DESIGN ASPECTS AS SYSTEM GEOMETRY, LOAD ONSET EFFECTS, AND TOTAL TRAJECTORY CONTROL SHOULD ALL BE INVESTIGATED AND INCORPORATED IN A PREDICTIVE FUNCTION IF PROVEN SIGNIFICANT.

R<DAT> 1976 R<AUT> FITZPATRICK, MICHAEL U.; STROTHER, CHARLES; EGBERT, TIMOTHY P. R<COR> MINICARS, INC., ENGINEERING STAFF(R<TTL> DEVELOPMENT OF ADVANCED RESTRAINT SYSTEMS FOR MINICARS RSV (RESEARCH SAFETY VEHICLE)

<FIL>DOTI 01H95750 R<SUP> PRESENTED AT SIXTH INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES, WASHINGTON, D.C., 12-16 OCT 1976. PROCEEDINGS TO BE PUBLISHED APR 1977. R<COL> 35P R<AVA> CORPORATE AUTHOR R<ISS> 77-03 R<ABS> PROTECTIVE FEATURES OF THE RESEARCH SAFETY VEHICLE (RSV) COMPARTMENT INTERIOR FOR THE DRIVER AND FRONT-SEAT PASSENGER WHICH PROVIDE PROTECTION LEVELS OF APPROXIMATELY 50 MPH (TESTED BOTH STATICALLY AND DYNAMICALLY) ARE A DUAL-BAG CONCEPT AND A FORCE-LIMITING CAPABILITY WHICH ENABLES OCCUPANT KINETIC ENERGY TO BE EFFICIENTLY ABSORBED WITHIN THE VEHICLE COMPARTMENT, THUS MINIMIZING INJURY INDICES. THE DUAL-BAG CONCEPT IS IMPLEMENTED IN THE DRIVER RESTRAINT BY TWO CONCENTRIC (INNER AND OUTER) BAGS. THE INNER (TORSO) BAG RECEIVES GAS DIRECTLY FROM THE INFLATOR AND VENTS TO THE OUTER HEAD BAG. IN THE PASSENGER RESTRAINT, A LARGE PARTITIONED BAG IS DIVIDED INTO AN UPPER AND A LOWER CHAMBER. THE LOWER CHAMBER TORSO RECEIVES AIR DIRECTLY FROM THE GAS INFLATOR AND VENTS TO THE UPPER HEAD CHAMBER. PROTECTION FOR THE OUT-OF-POSITION CHILD IS PROVIDED BY A SPECIAL BAG-FOLDING TECHNIQUE TO REDUCE EFFECTIVE BAG MASS, LOW INFLATOR MOUNT, PROPER ADJUSTMENT OF INFLATOR DOWN ANGLES FOR BAG IMPACT AT CHILD'S CENTER OF GRAVITY, AND A RECOIL ABSORBER. FORCE-LIMITING IN THE DRIVER SYSTEM OCCURS IN THE TELESCOPING OF THE STEERING COLUMN. IN THE FRONT PASSENGER RESTRAINT IT OCCURS IN THE STROKING OF THE RIGHT SIDE DASHBOARD. FORCE-LIMITING WAS ALSO INCORPORATED INTO THE RSV REAR SEAT THREE-POINT RESTRAINT SYSTEM TO EXTEND OCCUPANT PROTECTION CAPABILITY APPROACHING 45 MPH WITH RETRACTORS, WHICH EXCEEDS THAT PROVIDED BY CONVENTIONAL BELT SYSTEMS. RSV OCCUPANTS ARE PROTECTED IN SIDE IMPACT AND ROLLOVER ACCIDENTS BY THE STRONG SHUT FACES AND SECURE DOOR LATCHES OF THE GULLWING DOORS AS WELL AS THE WELL-PADDED, ROOMY INTERIOR AND THE FIXED SIDE GLAZING. VEHICLE-TO-VEHICLE SIDE IMPACT TEST RESULTS INDICATE THAT RSV NEAR AND FAR SIDE OCCUPANTS WOULD RECEIVE MINIMAL INJURY IN A 35 MPH IMPACT WITH A VEHICLE OF THE PINTO WEIGHT CLASS.

R<DAT> 1976 R<AUT> KALLERIS, D.; BARZ, J.; SCHMIDT, G.; HEESS, G.; MATTERN, R. R<COR> UNIVERSITY OF HEIDELBERG, WEST GERMANY(R<TTL> COMPARISON BETWEEN CHILD CADAVERS AND CHILD DUMMY BY USING CHILD RESTRAINT SYSTEMS IN SIMULATED COLLISIONS(

<FIL>DOTI 02H01490 R<CIT> HS-020 133 (SAE-P-66), "STAPP CAR CRASH CONFERENCE (20TH) PROCEEDINGS," WARRENDALE, PA., 1976 P511-422 R<COL> 18REFS R<REP> SAE-760815 R<AVA> IN HS-020 133 R<ISS> 77-05 R<ABS> A COMPARISON WAS MADE BETWEEN CHILD CADAVERS AND CHILD DUMMIES EQUIPPED WITH CHILD RESTRAINT SYSTEMS IN SIMULATED COLLISIONS. UNTIL NOW ONLY IMPACT TESTS USING DUMMIES AND ANIMALS HAD BEEN CONDUCTED. IN THIS STUDY, FRONTAL IMPACT TESTS WERE CONDUCTED USING A RESTRAINT SYSTEM CONSISTING OF A DEFORMABLE SAFETY IMPACT TABLE COMBINED WITH A LAP BELT. TWO DUMMIES AND FOUR CADAVERS OF CHILDREN AGED TWO, SIX (TWO CADAVERS), AND ELEVEN WITH BODY WEIGHT OF 16 UP TO 31 KG WERE USED ON A DECLERATION SLED TRACK WITH IMPACT VELOCITIES OF 30 KM/H AND 40 KM/H AT A MEDIUM DECELERATION OF 20G. NONE OF THE TEST SUBJECTS SHOWED INJURIES TO THE INNER ORGANS; HOWEVER, NUMEROUS MUSCULAR HEMORRHAGES AS WELL AS HEMORRHAGES OF DISCS AND LIGAMENTS WERE NOTICED. THE HIC (HEAD INJURY CRITERION) VALUES LAY BETWEEN 100 AND 500; ACCLERATIONS IN THE X-DIRECTION UP TO 44G AND IN Z-DIRECTION UP TO 85G OCCURRED AT THE HEAD. LAP-BELT FORCES OF 160 UP TO 4000AN WERE MEASURED. A WEAK POINT OF THE RESTRAINT SYSTEM IS SHOWN IN THE FACT THAT THE CHILD'S MOVEMENTS ARE CONSIDERABLY LIMITED, A FACTOR ALSO NOTICED IN OTHER CHILD SYSTEMS; HOWEVER, THE PROTECTIVE FUNCTION PROVED TO BE AN ADVANTAGE. THE MOVEMENTS DURING THE IMPACT, PICTURED BY HIGH-SPEED CAMERAS, ESSENTIALLY DIFFER FROM THOSE OF ADULTS WEARING 3-POINT BELTS. THE MAXIMUM FLEXION OF THE VERTEBRAL COLUMN IS, DUE TO THE SYSTEM, LOCATED IN THE TRANSITION OF THE THORACIC TO THE LUMBAR VERTEBRAL COLUMN; THE FLEXION ANGLES AMOUNTED TO ABOUT 90Ø. AS EXPECTED, THE MAXIMUM HEAD DISPLACEMENTS IN RELATION TO A SLED-FIXED AXIS WERE DEPENDENT ON THE IMPACT VELOCITY AND THE BODY HEIGHT, AND RANGED BETWEEN 50 CM (CRASH VELOCITY 30 KM/H, BODY HEIGHT 97 CM) AND 90 CM (CRASH VELOCITY 40 KM/H, BODY HEIGHT 139 CM). RESULTS SHOW THAT THE CHILD CADAVER AND CHILD DUMMY KINEMATICS ARE SIMILAR DURING THE FRONTAL IMPACT. ALSO, THE BELT LOAD HISTORY AS WELL AS THE COURSE OF THE RESULTANT HEAD DECELERATIONS CORRESPOND TO A GREAT EXTENT. DESPITE A LOWER DUMMY WEIGHT, HIGHER FORCE MAXIMA WERE MEASURED THAN IN THE CADAVER. SIGNIFICANT DIFFERENCES WERE OBSERVED IN THE FLEXION BEHAVIOR OF THE VERTEBRAL COLUMN. IT IS CONCLUDED THAT THE DUMMY IS SUITED FOR PRELIMINARY EXAMINATIONS OF CHILD SAFETY DEVICES; HOWEVER, CHILD CADAVER TESTS ARE INDISPENSABLE FOR THE INVESTIGATION OF THE TOLERANCE LIMIT. IT IS EMPHASIZED THAT THE SEMI-CYLINDRICAL SHAPED SAFETY TABLE CAUSES A LOWER COMPRESSIVE LOAD ON THE ABDOMINAL REGION AND THUS PROTECTS THE INNER ORGANS.

R<DAT> 1976 R<AUT> MASSING, DANIEL E.; KOSTYNIUK, GREGORY W.; PUGLIESE, SAVERIO M. R<COR> CALSPAN CORP. R<TTL> CRASH VICTIM SIMULATION--A TOOL TO AID VEHICLE RESTRAINT SYSTEM DESIGN AND DEVELOPMENT(

<FIL>DOTI 01H95770 R<SUP> PRESENTED AT SIXTH INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES, WASHINGTON, D.C., 12-16 OCT 1976. PROCEEDINGS TO BE PUBLISHED APR 1977. R<COL> 28P 12REFS R<AVA> CORPORATE AUTHOR R<ISS> 77-03 R<ABS> RECENTLY, THE CRASH VICTIM SIMULATION (CVS) PROGRAM WAS USED AS THE BASIS FOR DESIGN STUDIES OF ADVANCED AIR BAG AND LAP-TORSO BELT RESTRAINT SYSTEMS. IN THESE STUDIES CANDIDATE RESTRAINT SYSTEMS WERE ANALYTICALLY EVALUATED IN SPECIFIC VEHICLE ACCELERATION ENVIRONMENTS PRIOR TO THE PERFORMANCE OF SLED TESTS OF ACTUAL HARDWARE. THE MODEL OF THE CRASH VICTIM CONSISTS OF 15 SEGMENTS AND 14 JOINTS TO REPRESENT THE HUMAN BODY. MEASUREMENTS OF VEHICLE INTERIOR GEOMETRY PROVIDED THE DATA FOR SIMULATION INPUT. THE RSV BASE VEHICLE, SIMCA 1307, AND THE VEHICLE SELECTED FOR INSTALLATION OF THE ASPIRATED AIR BAG SYSTEM, VOLVO 244 DL, WERE SELECTED FOR INPUT MEASUREMENTS OF MUTUAL FORCE-DEFLECTION CHARACTERISTICS FOR THE OCCUPANT CONTACT PLANE. SETS OF COLD GAS INFLATION SYSTEMS INPUT PARAMETERS HAD TO BE DEVELOPED FROM EXISTING DATA FROM AN INFLATION SYSTEM CONTAINING A PYROTECHNIC HOT GAS GENERATOR. ADJUSTMENTS WERE MADE IN MEASUREMENTS OF THE AIR BAG TO PROVIDE THE CORRECT VOLUME FOR SIMULATION. TWENTY-THREE SIMULATION RUNS AND THREE SLED RUNS WERE MADE IN THE RSV PROGRAM. IN THE ASPIRATED AIR BAG INFLATOR PROGRAM, A 50-LB SIMULATED CHILD OCCUPANT WAS USED, ALONG WITH A SIMULATED SEATED 50TH PERCENTILE MALE OCCUPANT. SEVEN SIMULATIONS WERE PERFORMED, AND RESULTS FROM ONE SLED TEST SHOWED THE TEST CONFIGURATION CLOSELY MATCHED THE INPUT OF A SIMULATION RUN. IN THE BELT RESTRAINT SYSTEM SIMULATIONS RSV PROGRAM, A LIMITED SERIES OF RUNS SIMULATING THE 35-MPH BARRIER CRASH OF THE C-6 BASE VEHICLE WAS PERFORMED. A 1975 PLYMOUTH LAP/SHOULDER BELT SYSTEM WAS USED ON A FRONT SEAT PASSENGER PART 572 DUMMY. RESULTS PROVIDED CONFIDENCE IN THE PREDICTIVE CAPABILITY OF THE CVS IN A PLANNED SERIES OF PARAMETER VARIATION RUNS. IN THE ADVANCED BELT SYSTEM DEVELOPMENT MOST OF THE INPUT DATA USED REMAINED INTACT THROUGHOUT THE STUDY. CHANGES WERE THOSE MANDATED BY GEOMETRICAL DESIGN OR BY ADDITION OF NEW RESTRAINT SYSTEM COMPONENTS. THE EFFECTS OF INTRUSION WERE INCORPORATED BY PERFORMING SEVERAL RUNS WITH VARIOUS POSITIONS OF THE DASHBOARD. THE RESULTS OF THE BELT RESTRAINT SYSTEM SIMULATIONS INDICATE GOOD CORRELATION BETWEEN THE MEASURED RESPONSES AND THE PREDICTIONS OF THESE RESPONSES BY THE CVS MODEL. A SMALL NUMBER OF IMPACT SLED VALIDATION TESTS WERE RUN EMPLOYING DUMMIES IN A RESTRAINT SYSTEM RESEMBLING THE SIMULATED BELT SYSTEMS TO PROVIDE VALIDATION DATA FOR THE CVS PROGRAM CONFIGURATION USED IN THIS STUDY. THE RESULTS WERE NOT AS GOOD AS THE BASELINE VALIDATION RUNS BECAUSE OF AN INABILITY TO SIMULATE THE ACTUAL RESTRAINT PROPERTIES WITH INPUT DESCRIBING THE INFLATED BELT CHARACTERISTICS IN TERMS OF EQUIVALENT WEBBING ELONGATION. MEASUREMENTS SUCH AS THESE INVOLVE ELABORATE EXPERIMENTAL EFFORTS BEYOND THE SCOPE OF THIS VALIDATION EFFORT. RECENT VALIDATION EFFORTS TO EXPLAIN AND ELIMINATE PHASE DISAGREEMENT HAVE BEEN PERFORMED. IN

ONE SUCH PROGRAM, BAGFIL, PARTICULAR ATTENTION WAS PAID TO THE DEVELOPMENT OF IMPROVED DESCRIPTIONS OF PARAMETERS RELATED TO CHOICES FOR THE CVS BAG INFLATION AND VENTING ALGORITHMS AND BAG DEPLOYMENT GEOMETRY, THOUGHT TO BE THE CAUSES OF PHASE SHIFT. THE RESULTS OF BAGFIL SHOW THE MEASURED HEAD AND UPPER TORSO DISPLACEMENTS TO BE IN MUCH CLOSER AGREEMENT WITH PREDICTED VALUES THAN WERE PREVIOUS SIMULATION RESULTS. FUTURE PLANS CALL FOR PROGRAMS TO DETERMINE FURTHER VALIDATION OF THE CVS MODEL AND WILL ENCOMPASS VARIABLES NOT INCLUDED THUS FAR.

R<DAT> 1976 R<AUT> MILLER, PATRICK M. R<COR> CALSPAN CORP. R<TTL> A STATUS REPORT ON THE CALSPAN/CHRYSLER RSV (RESEARCH SAFETY VEHICLE)(<FIL>DOTI 01H95620 R<SUP> PRESENTED AT SIXTH INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES, WASHINGTON, D.C., 12-16 OCT 1976. PROCEEDINGS TO BE PUBLISHED APR 1977. R<COL> 32P 8REFS R<AVA> CORPORATE AUTHOR R<ISS> 77-03

R<ABS> THE CALSPAN/CHRYSLER RSV (RESEARCH SAFETY VEHICLE) PROGRAM APPROACH IS BASED ON DERIVATION OF THE RSV FROM A CURRENT STATE-OF-THE-ART PRODUCTION AUTOMOBILE BECAUSE ONLY INCREMENTAL DESIGN CHANGES BETWEEN THE BASE VEHICLE AND THE RSV NEED TO BE INVESTIGATED TO ESTABLISH THE PRODUCTION FEASIBILITY OF THE RESULTING DESIGN. BASIC GEOMETRICAL DESIGN, DRIVE SYSTEM, CHASSIS, AND OTHER PROPERTIES OF THE BASE VEHICLE ARE REFLECTED IN THE RSV DESIGN. THE SIMCA 1308 WAS SELECTED AS THE BASE VEHICLE SINCE IT REPRESENTS ADVANCED ENGINEERING PRACTICE. EXTENSIVE ACTIVE AND CRASH SAFETY TESTS PERFORMED WITH THE BASE VEHICLE INDICATED THAT NEARLY ALL OF ITS ACTIVE SAFETY CHARACTERISTICS (BRAKING, HANDLING, ETC.) MET OR EXCEEDED RSV REQUIREMENTS. AN EXCEPTION WAS NOTED WHEN A FRONT BRAKE SYSTEM FAILURE CONDITION WAS SIMULATED AND THE SPECIFIED STOPPING DISTANCE WAS EXCEEDED. RSV DEVELOPMENT WAS DIVIDED INTO THREE CATEGORIES, STYLING, CRASH SAFETY, AND VEHICLE SYSTEMS; PRINCIPAL EFFORT WAS EXPENDED ON CRASH SAFETY. AN ATTEMPT WAS MADE TO CARRY OVER TO THE RSV A MAXIMUM NUMBER OF BASE VEHICLE EXTERIOR AND INTERIOR PARTS, BUT IN VIEW OF PEDESTRIAN IMPACT REQUIREMENTS, A COMPLETELY DIFFERENT FRONT FACIA WAS NECESSARY. CRASH SAFETY ACTIVITY WAS DIVIDED INTO CATEGORIES OF BUMPER, STRUCTURE, AND INTERIOR-RESTRAINTS. A HIGH-DENSITY URETHANE FOAM SKIN WITH CRASH ENERGY MANAGEMENT PROVIDED BY A LOW ENERGY ABSORBING FOAM WAS EMPLOYED TO MAKE A BUMPER WHICH WOULD PROVIDE PEDESTRIAN PROTECTION AND MINIMIZE VEHICLE DAMAGE DURING LOW-SPEED COLLISIONS. STEEL WAS THE PRIMARY STRUCTURAL COMPONENT AND MAJOR CHANGES WERE MADE IN THE FRONT AND SIDE STRUCTURAL COMPONENTS. CRUSH TESTS PRECEDED THE DESIGN CHANGES. VEHICLE COMPATIBILITY WAS EXTENSIVELY INVESTIGATED THROUGHOUT THE STRUCTURAL DEVELOPMENT TO INSURE THE RSV WOULD NOT HAVE A SEVERE ADVERSE EFFECT ON OTHER HEAVIER AND LIGHTER CARS. THE RSV FRONT SEAT RESTRAINT IS A PASSIVE TORSO BELT, OPTIONALLY SEMIPASSIVE LAP BELT SYSTEM DEVELOPED USING THE CALSPAN CRASH VICTIM SIMULATION MODEL AND EVALUATED WITH THE CALSPAN HYGE SLED. THE REAR SEAT OCCUPANT RESTRAINT IS A CONVENTIONAL THREE-POINT UNIBELT SYSTEM, EXCEPT THAT FORCE LIMITING IS PROVIDED IN THE UPPER TORSO BELT. A SPECIAL ENERGY-ABSORBING DOOR TRIM PANEL WAS DEVELOPED TO PROVIDE ENERGY MANAGEMENT DURING LATERAL COLLISIONS. INCOMPLETE PRELIMINARY SYSTEM INTEGRATION TEST RESULTS INDICATE THAT THERE IS IMPROVED STRUCTURAL PERFORMANCE IN THE RSV AFTER 45 MPH BARRIER IMPACTS, AND THAT ALL MEASURED PARAMETERS NEARLY MEET THE INJURY CRITERIA FOR VEHICLE OCCUPANTS. A DIAGONAL SPLIT BRAKING SYSTEM AND A CHANGED POWER PLANT ARE THE ONLY TWO MAJOR VEHICLE SYSTEMS CHANGES MADE BETWEEN THE BASE VEHICLE AND THE RSV. TABULATED MATERIAL, DIAGRAMS, AND PHOTOGRAPHS ILLUSTRATE TEST RESULTS.

R<DAT> 1976 R<AUT> PATRICK, L. M. R<COR> WAYNE STATE UNIV., BIOMECHANICS RES. CENTER(R<TTL> FRONTAL FORCE IMPACT TOLERANCE OF THE HUMAN THORAX(

<FIL>DOTI 01H99760 R<CIT> HS-019 973 (SAE-P-67), "THE HUMAN THORAX--ANATOMY, INJURY, AND BIOMECHANICS," WARRENDALE, 1976 P37-488 R<CUL> 34REFS R<AVA> IN HS-019 973 R<ISS> 77-04 R<ABS> THE IMPACT TOLERANCES OF THE AREAS OF THE HUMAN THORAX WHICH ARE SUBJECT TO INJURY IN FRONTAL FORCE IMPACTS ARE DESCRIBED. THE STERNUM AT THE ANTERIOR TERMINATION OF RIBS ONE TO SEVEN IS ONE OFTEN INJURED AREA. THE THORACIC SPINE WHICH CONSISTS OF 12 VERTEBRAE IS AN IMPORTANT PART OF THE THORAX WHICH IS INJURED LESS OFTEN THAN THE RIBS, BUT WHICH WHEN INJURED OFTEN RESULTS IN MORE SERIOUS INJURY SUCH AS PARAPLEGIA OR QUADRAPLEGIA. INJURIES TO THE THORACIC SPINE ARE GENERALLY PRODUCED BY BENDING, COMPRESSION, AND COMBINATIONS OF BENDING AND COMPRESSION. THE CLAVICLES ARE OF PARTICULAR INTEREST SINCE THEIR LOCATION MAKES THEM PRONE TO IMPACT LOADING AND INJURY FROM SHOULDER BELT, A-POST, AND STEERING WHEEL RIM. RIBS ARE THE MOST VULNERABLE TORSO SKELETAL COMPONENT IN FRONTAL FORCE AUTOMOBILE ACCIDENTS. SEVERAL TEST RESULTS ARE CITED WHICH SHOW THAT RIB FRACTURES ARE THE MOST COMMON ACCIDENT INJURY. THE TYPES OF LOADING ON THE THORAX IN FRONTAL FORCE AUTOMOBILE ACCIDENTS ARE DESCRIBED. LOADING CAN BE UNIFORM, CONCENTRATED, CRUSHING, AND COMBINATIONS OF THESE TYPES. CONCENTRATED FORCES CAUSE DAMAGE TO INDIVIDUAL RIBS OR SMALL AREAS OF SOFT TISSUE. CRUSHING OCCURS OCCASIONALLY FROM GROSS DEFORMATION OF THE VEHICLE OR FROM LOADING OF FRONT SEAT OCCUPANTS BY REAR SEAT OCCUPANTS. HUMAN THORAX IMPACT TOLERANCE IS DEFINED AS THE QUANTITATIVE RESPONSE TO IMPACT OF THE THORAX CORRESPONDING TO A PREDETERMINED DEGREE OF INJURY IN AN AVERAGE INDIVIDUAL. VARIOUS LEVELS OF IMPACT TOLERANCE THAT HAVE BEEN CONSIDERED ARE DISCUSSED, AND THE MANY VARIABLES AFFECTING TOLERANCE ARE PROVIDED. PARAMETERS USED TO DESCRIBE IMPACT CONDITIONS AND/OR TOLERANCE INCLUDE THE VARIABLES OF AGE, SEX, SIZE, PHYSICAL CONDITION, AND TYPE OF EXPOSURE. TOLERANCE IS PRESENTED AS THE TOLERANCE OF THE AVERAGE INDIVIDUAL WITH THE LIKELIHOOD OF INJURY ESTIMATED. THE UNRESTRAINED OCCUPANT REPRESENTS THE CONDITION WITH THE MAXIMUM NUMBER OF VARIABLES IN FORWARD FORCE AUTOMOBILE ACCIDENTS, AND SO INJURIES CAN BE APPROACHED STATISTICALLY. DISCUSSION OF RESTRAINED OCCUPANTS IS DIVIDED INTO SECTIONS BY THE TYPE OF RESTRAINT. TESTS HAVE SHOWN THAT LAP AND LAP AND SHOULDER BELTS ARE EFFECTIVE IN REDUCING OVERALL INJURY AT THE ABBREVIATED INJURY SCALE TWO (AIS) AND GREATER LEVEL. THE DISCUSSION OF TOLERANCE LEVELS IS LIMITED TO INDIVIDUAL EXPOSURE CONDITIONS. THE PRIMARY CONDITIONS CONSIDERED FOR FRONTAL FORCE COLLISIONS ARE: ACCIDENT INVESTIGATION RESULTS; LABORATORY TESTS WITH CHEST IMPACT BY A MOVING IMPACTOR; LABORATORY DATA UNDER SIMULATED COLLISION CONDITIONS; AND COMBINED ACCIDENT INVESTIGATION AND LABORATORY DATA. IN THE AUTOMOBILE COLLISION ENVIRONMENT, THERE IS LITTLE APPLICABLE TOLERANCE DATA FOR UNRESTRAINED OCCUPANTS SINCE THE AREA, DIRECTION, AND MAGNITUDE OF FORCE APPLIED TO THE TORSO IN A COLLISION CANNOT BE ANTICIPATED. TEST RESULTS HAVE YIELDED LIMITED DATA ON TOLERANCE OF THE HUMAN THORAX.

R<DAT> 1976 R<AUT> QUINCY, R.; DEJEAMMES, M. R<COR> ONSER--LABORATOIRE DES CHOCS ET DE BIOMECANIQUE, 109 AV. SALVADOR ALLENDE, 69500(R<TTL> ANALYSIS OF THE PRELOADED SAFETY BELT RESTRAINT WITH AN ANIMAL(

<FIL>DOTI 02H02540 R<CIT> HS-020 247, "PROCEEDINGS OF THE 20TH CONFERENCE OF THE AMERICAN ASSOC. FOR AUTOMOTIVE MEDICINE," MORTON GROVE, ILL., 1976 P60-722 R<SUP> PRESENTED AT THE CONFERENCE HELD IN ATLANTA, GA., 1-3 NOV 1976. R<COL> 7REFS R<AVA> IN HS-020 247 R<ISS> 77-06 R<ABS> THE EFFICIENCY OF THE SEAT BELT PRELOAD DEVICE DURING IMPACT WAS EVALUATED. THE DEVICE IS DESIGNED TO IMPROVE THE THREE-POINT BELT RESTRAINT BY ENSURING A BETTER COUPLING BETWEEN THE CAR AND THE OCCUPANT AT THE BEGINNING OF IMPACT. A LIVING MODEL, THE BABOON, WAS CHOSEN BECAUSE OF ITS PSYSIOLOGICAL SIMILARITY WITH MAN, TO TEST THE BELT'S ABILITY TO LESSEN COMPRESSIVE LOADS ON THE THORAX. IMPACT TESTS WERE CONDUCTED ON A DYNAMIC SLED AT SPEEDS OF 8.3 AND 13 M/S. TO REDUCE THE NUMBER OF VARIABLES, THE BABOON WAS PLACED ON A RIGID SEAT AND WAS RESTRAINED BY A FOUR POINT HARNESS WHICH PREVENTED LATERAL MOVEMENT. THE PRELOAD WAS APPLIED ON THE SHOULDER STRAPS. THE FIRST STAGE OF THE EXPERIMENT CONSISTED OF APPLICATION OF THE PRELOAD LEVEL JUST PRIOR TO IMPACT IN ORDER TO DEFINE REALISTIC LEVELS. TEST ANALYSIS INCLUDES THE STUDY OF THE ANIMAL KINEMATICS AND THE SHOCK PARAMETERS, HEAD AND THORAX DECELERATIONS, AND STRAP LOADS. THE ANALYSIS INDICATES THAT PRELOAD LEVEL HAS A GREAT INFLUENCE ON THE PARAMETERS MEASURED. IT IS CONCLUDED THAT PRELOAD APPLIED BEFORE IMPACT GREATLY IMPROVES THE PROTECTION AFFORDED BY A SEAT BELT. APPLICATION OF THE PRELOAD REDUCED BOTH THE AMPLITUDE OF THE BABOON'S MOVEMENT AND THE DECELERATION LEVELS. USAGE OF A LIVING ANIMAL MODEL HELPED TO ASSESS POSSIBLE RISKS SPECIFIC TO THE PRELOAD DEVICE. IT WAS FOUND THAT A 120 DAN PRELOAD WAS THE LIMIT THAT COULD BE APPLIED TO THE BABOON'S HARNESS BEFORE THORACIC FRACTURES OR RESPIRATORY DISTURBANCES OCCURRED. THE SECOND STAGE OF THE WORK IS BEING CONDUCTED AND CONSISTS OF APPLICATION OF PRELOAD BY MEANS OF PYROTECHNICAL JACKS INITIATED BY IMPACT. IT IS HOPED THAT RESULTS WILL BE OBTAINED WHICH PARALLEL THOSE OBTAINED IN THIS STAGE OF THE WORK.

R<DAT> 1976   R<AUT> SCHEUER, JAMES H.; SHUSTER, BUD   R<TTL> SHOULD SEAT BELT USAGE BE MANDATED BY LAW?¬ PRO. CON(
<FIL>DOT1 01H91840   R<CIT> MOTOR TREND V28 N8 P40-2, 99 (AUG 1976)6
R<AVA> SEE PUBLICATION   R<ISS> 77-01   R<ABS> PRO AND CON STATEMENTS CONCERNING THE LEGAL MANDATE FOR SEAT-BELT USAGE ARE PRESENTED BY TWO CONGRESSMEN. AS FOR THE POSITION IN FAVOR, FACTORS INDICATING THE NEED FOR MANDATORY SEAT-BELT USE LAWS INCLUDE THE SAVING OF LIVES (APPROXIMATELY 9,000/YEAR) AND REDUCING SERIOUS INJURIES (ESTIMATED AT 120,000/YEAR). COMPULSORY SAFETY-BELT USAGE IN VARIOUS FOREIGN COUNTRIES IS CITED TO ILLUSTRATE SUCH HUMAN SAVINGS, E.G., AUSTRALIA REPORTED THAT SUCH LAWS INCREASED THE USAGE RATE OF BELTS FROM 25% TO 80%, AND THE DEATH AND INJURY RATES DROPPED BY 25% AND 30%, RESPECTIVELY. ALTHOUGH A POLL IN THE U.S. INDICATED THAT 53% OF THE AMERICAN PUBLIC WOULD NOT OBJECT TO MANDATORY USE LAWS, PROGRESS IN THEIR PASSAGE HAS BEEN THWARTED BY THE "BIG BROTHER" ARGUMENT WHICH HOLDS THAT GOVERNMENT DOES NOT HAVE THE RIGHT TO FORCE INDIVIDUALS TO PROTECT THEMSELVES. THE INVOLVEMENT OF THE PUBLIC WITH AN INDIVIDUAL'S RIGHT TO INJURE HIMSELF AND HIS PASSENGERS AND PERHAPS CAUSE THE PUBLIC TO PAY FOR HIS AND HIS VICTIMS' INJURIES AND THEIR UPWARD PRESSURE ON INSURANCE RATES IS DESCRIBED, CONCLUDING THAT A MANDATORY SEAT-BELT USE LAW IS JUSTIFIED AND NEEDED IN THE U.S. THE ARGUMENT AGAINST MANDATORY SEAT-BELT USE LAWS CENTERS UPON THREE NEEDS FOR GOOD LEGISLATION WHICH THE LAW SUGGESTED CANNOT SUPPLY: FIT THE SITUATION OR ILL THAT IT IS INTENDED TO CORRECT, BE EFFECTIVE IN CORRECTING IT, AND NOT CREATE ADDITIONAL PROBLEMS WHICH OUTWEIGH THE INTENDED BENEFITS. PRINCIPALLY, IT IS CONTENDED THAT INDIVIDUAL LIABILITY IS LIMITED TO THE EFFECTS UPON OTHERS RATHER THAN UPON ONE'S SELF. IT IS SUGGESTED THAT LAWS PROHIBITING SELF-DESTRUCTIVE BEHAVIOR ARE USELESS, INCORPORATING INEFFICIENCY IN DEFEATING BAD DRIVING HABITS, DIFFICULTY IN ENFORCEMENT, AND ETHICAL BASENESS. IT IS SUGGESTED INSTEAD THAT SAFETY-BELT USAGE COULD BE PROMOTED BY EDUCATIONAL PROGRAMS, MEDIA CAMPAIGNS, LEGISLATIVE ENDORSEMENTS, ROAD-SIGN INFORMATION PROGRAMS, AND DEVELOPMENT OF MORE COMFORTABLE BELT SYSTEMS. CONCURRENTLY, PREVENTION OF AUTOMOBILE INJURIES BY USE OF PASSIVE RESTRAINTS IS FAVORED.

R<DAT> 1976   R<AUT> SEIFFERT, U.   R<COR> VOLKSWAGENWERK AG, GERMANY(
R<TTL> RESTRAINT SYSTEMS FOR OCCUPANT PROTECTION(
<FIL>DOTI 01H88450   R<SUP> PRESENTED AT SEAT BELT SEMINAR, MELBOURNE, AUSTRALIA, 9-11 MAR 1976, SPONSORED BY COMMONWEALTH DEPARTMENT OF TRANSPORT.
R<COL> 21P 4REFS   R<REP> PAPER-7   R<AVA> IN HS-018 935   R<ISS> 76-11   R<ABS> THE STATE OF THE ART FOR SEAT BELT SYSTEMS AND THEIR DYNAMIC BEHAVIOR IN SIMULATED CRASHES ARE DESCRIBED. AUSTRALIAN LEGISLATION REQUIRES 3-POINT AUTOMATIC BELTS FOR FRONT SEAT OCCUPANTS, AND 3-POINT BELTS FOR REAR SEAT OUTBOARD SEATING POSITIONS. MOST EUROPEAN COUNTRIES DO NOT SPECIFY PARTICULAR TYPES OF SEAT BELTS, BUT SOME SPECIFICATIONS ARE PROVIDED FOR SEAT BELT MATERIALS AND AUTOMATIC BELT RETRACTOR LOCKING LEVELS. THERE ARE ALSO SOME REQUIREMENTS APPLYING TO DYNAMIC SEAT BELT TEST PROCEDURES. THE DYNAMIC BEHAVIOR OF RESTRAINT SYSTEMS IS SHOWN TO BE DEPENDENT ON FACTORS SUCH AS VEHICULAR VELOCITY CHANGE AND DECELERATION LEVEL, MATERIALS TOLERANCE, AND BELT SLACK IN USAGE OF RESTRAINT SYSTEMS BY INDIVIDUALS. A DYNAMIC SEAT BELT TEST WITH SPECIFIC INJURY CRITERIA FOR EVALUATION OF PERFORMANCE IS RECOMMENDED. SOME ATTENTION IS ALSO GIVEN TO THE CONTRIBUTION OF PASSIVE RESTRAINT SYSTEMS TO COMFORT, WITH SPECIFIC INFORMATION ON THE PASSIVE SYSTEM USED IN THE VOLKSWAGEN GOLF. COMMENTS ARE MADE ON ADDITIONAL RESEARCH REQUIRED TO PROVIDE INFORMATION ON THE USEFULNESS OF FORCE LIMITERS AND PRELOADED BELT SYSTEMS. IT IS RECOMMENDED THAT UNIFORM INTERNATIONAL STANDARDS BE DEVELOPED FOR SEAT BELT TESTING.

R<DAT> 1975 R<COR> UNIVERSITY OF SASKATCHEWAN, TRANSPORTATION CENTRE, SASKATOON, SASK., CANADA R<TTL> MULTIDISCIPLINARY ACCIDENT INVESTIGATION. KENWORTH SEMI-TRAILER/OLDSMOBILE CUTLASS/TYPE "L" INTERSECTION/KENWORTH SEMI-TRAILER/NOVA/TYPE "T" INTERSECTION/NOVA/LIGHT STANDARD/FIXED OBJECT

<FIL>DOTI 01H86520 R<SUP> INCLUDES FRENCH AND ENGLISH SUMMARIES. R<COL> 105P R<REP> UOS-048-75 R<AVA> DIRECTOR, ROAD AND MOTOR VEHICLE TRAFFIC SAFETY, MINISTRY OF TRANSPORT, OTTAWA, ONT., CANADA R<ISS> 76-10 R<CON> 96101 R<ABS> A FULL REPORT OF A THREE-VEHICLE ACCIDENT IS PRESENTED. THE DRIVER OF A 1962 KENWORTH CANADIAN TRACTOR AND LOADED SEMI-TRAILER WAS PROCEEDING ON A MAJOR FOUR-LANE LIMITED ACCESS HIGHWAY AT ABOUT 40 MPH. AS HE APPROACHED A SIGNALIZED INTERSECTION AT THE END OF THE HIGHWAY, THE TRUCK'S BRAKES MALFUNCTIONED AND THE TRUCK WENT INTO THE INTERSECTION AGAINST A RED LIGHT. THE TRUCK STRUCK THE RIGHT REAR FENDER OF A 1974 OLDSMOBILE SEDAN AND THE BROADSIDE OF A 1973 CHEVROLET NOVA WHICH WERE TRAVELING THROUGH THE INTERSECTION ON A GREEN LIGHT. THE TRUCK DRIVER WAS UNINJURED. THE DRIVER AND PASSENGER OF THE OLDSMOBILE RECEIVED MINOR INJURIES AND WERE RELEASED FROM THE HOSPITAL AFTER EXAMINATION. THE DRIVER OF THE NOVA WAS KNOCKED UNCONSCIOUS UPON IMPACT AND RECEIVED WHIPLASH INJURIES TO HER NECK. SHE WAS ALSO RELEASED FROM THE HOSPITAL AFTER EXAMINATION. THE NOVA WAS DAMAGED BEYOND ECONOMIC REPAIR. THE FOLLOWING INFORMATION IS PROVIDED: A CASE SUMMARY; DESCRIPTIONS OF THE HUMAN, VEHICLE AND ENVIRONMENTAL FACTORS OF THE PRE-CRASH, CRASH, AND POST-CRASH PHASES; AN ACCIDENT CAUSATION LISTING; SEAT BELT USE; AN ACCIDENT SCHEMATIC; PHOTOGRAPHS OF THE VEHICLE ACCIDENT DAMAGE AND THE ACCIDENT SCENE; RESULTS FROM PSYCHOLOGICAL INTERVIEWS WITH THE DRIVER OF THE OLDSMOBILE AND NOVA; AND COMPLETE COLLISION PERFORMANCE AND INJURY REPORT FORMS FOR THE TRUCK AND THE OLDSMOBILE. IT WAS DETERMINED THAT, DUE TO AGING, THE LINE TO THE ACTIVATION SIDE OF THE TRAILER BRAKES ON THE TRUCK DEVELOPED A LEAK AND CAUSED BRAKE FAILURE ON THE TRAILER PORTION OF THE UNIT. THE ACCIDENT DAMAGE COSTS WERE DETERMINED TO BE: $500 FOR THE TRUCK; $1000 FOR THE OLDSMOBILE; AND $2600 FOR REPLACEMENT OF THE NOVA.

R<DAT> 1975   R<AUT> HARTEMANN, F.; TARRIERE, C.; MACKAY, G. M.; GLOYNS, P. F.; HAYES, H. R. M.; CESARI, M., D., M. RAMET   R<COR> ASSOCIATION PEUGEOT-RENAULT, LAB. DE PHYSIOLOGIE ET DE BIOMECANIQUE, FRANCE; UNIVERSITY OF BIRMINGHAM, DEPT. OF TRANSPORTATION AND ENVIRONMENTAL PLANNING, EN O.N.S.E.R. (LYON), LABORATOIRE DES CHOCS ET DE BIOMECANIQUE, FRANCE(R<TTL> HOW TO FURTHER IMPROVE THE PROTECTION OF OCCUPANTS WEARING SEAT BELTS(

<FIL>DOTI 01H79510   R<CIT> HS-017 947, CONFERENCE OF THE AMERICAN ASSOCIATION FOR AUTOMOTIVE MEDICINE (19TH) PROCEEDINGS, LAKE BLUFF, ILL.,1975, P36-48(R<SUP> CONFERENCE HELD IN SAN DIEGO, CALIF., 20-22NOV 1975.   R<COL> 5REFS   R<AVA> IN HS-017 947   R<ISS> 76-06 R<ABS> THE DIFFERENCES BETWEEN THE THEORETICAL AND THE OBSERVED PERFORMANCES OF SAFETY BELTS AND THE FACTORS CAUSING INJURIES IN OBSERVED CASES WERE INVESTIGATED BY ANALYZING 420 ACCIDENTS IN GREAT BRITAIN AND FRANCE IN WHICH AT LEAST ONE OCCUPANT WAS INJURED. THE OCCUPANTS OF THE CARS INVOLVED IN ACCIDENTS INCLUDED 390 DRIVERS AND 211 PASSENGERS, OF WHOM 276 DRIVERS AND 164PASSENGERS WERE INJURED WHILE WEARING SEAT BELTS. THE ACCIDENTS INCLUDED: 292 FRONTAL IMPACTS; 33 REAR IMPACTS; 49 LATERAL IMPACTS; AND 46 ROLLOVERS. THE MOST SERIOUS INJURIES SUSTAINED IN FRONTAL IMPACTS INVOLVE HEAD, THORAX, AND ABDOMEN INJURIES. SEAT BELT EFFICIENCY IN FRONTAL COLLISIONS WAS FOUND TO BE LIMITED BY: INTRUSION INTO THE CAR OF EXTERNAL ELEMENTS; SEAT BELT FAILURES; MOVEMENT OF THE STEERING WHEEL CENTER; FOR 27% OF THE INJURED, WEARING THE SEAT BELT TOO SLACKLY; AND OVERLOADING BY THE PROJECTION OF THE REAR SEATPASSENGER. SUGGESTED COUNTER MEASURES FOR REDUCING INJURIES IN FRONTAL COLLISIONS INCLUDE: IMPROVING THE RESTRAINT SYSTEM GEOMETRY; STRUCTURAL REINFORCEMENT OF THE CAR; AND RETENTION OF REAR SEAT OCCUPANTS. LIMITATION OF STEERING WHEEL MOVEMENT AND THE PROVISION OF STEERING WHEEL PADDING WOULD BE SUFFICIENT TO AVOID MOST SERIOUS HEAD INJURIES TO DRIVERS. BELT IMPROVEMENTS SHOULD BE DESIGNED TO IMPROVE THE PROTECTION OF THE THORACIC CAGE. WIDENING THE BELT AND PROVIDING A LOAD LIMITER HAVE SHOWN GOOD RESULTS IN THIS RESPECT. IN NO CASE WAS NOT WEARING A SEAT BELT SHOWN TO BE AN OBVIOUS COUNTERMEASURE TO INJURY TO OCCUPANTS OF A CARINVOLVED IN AN ACCIDENT.

R<DAT> 1975 R<AUT> KALLIERIS, D.; MEISTER, B.; SCHMIDT, G. R<COR> UNIVERSITY HEIDELBERG, INST. FOR FORENSIC MEDICINE(R<TTL> REACTIONS OF THE CERVICAL SPINE DURING FRONTAL IMPACTS OF BELT PROTECTED CADAVERS(

<FIL>DOTI 01H80700 R<CIT> HS-018 062, BIOMECHANICS OF SERIOUS TRAUMA, INTERNATIONAL CONFERENCE (2ND) PROCEEDINGS, AMSTERDAM, P126-42(R<SUP> CONFERENCE HELD IN BIRMINGHAM, 9-11 SEP 1975, SPONSOREDIN PART BY FORSCHUNGSVEREINIGUNG AUTOMOBILTECHNIK E.V., FRANKFURT, WEST GERMANY. PREPARED IN COOPERATION WITH F. SCHULZ AND VOLKSWAGENWERK AG. R<COL> 19REFS R<AVA> IN HS-018 062 R<ISS> 76-06 R<ABS> FIFTY-NINE FRONTAL BARRIER TESTS WITH HUMAN CADAVERS WERE CARRIED OUT USING POINT-STANDARD SAFETY BELT WITH AUTOMATIC RETRACTOR (34 CASES); THREE-POINT-BELT WITH FORCE LIMITOR AND PRELOADING DEVICE (THREE CASES); TWO-POINT-BELT WITH KNEEBAR (FOUR CASES); AND TWO-POINT-BELT, AUTOMATIC RETRACTOR WITH FORCE LIMITOR AND PRELOADING DEVICE (18 CASES). THE IMPACT SPEED WAS 30 KILOMETERS PER HOUR (KM/H) (TWO TESTS); 40 KM/H (FIVE TESTS); 50 KM/H (47 TESTS); AND 65 KM/H (FIVE TESTS). THE OBSERVED INJURY DEGREES (PATHO-ANATOMICAL OBSERVED AIS SCALE) RUN UP TO ZERO AT THREE CASES, TO ONE AT FOUR CASES, TO TWO AT 13 CASES, TO THREE AT 29 CASES, AND TO FOUR AT TEN CASES. THE SEVERITY DEGREE WAS INCREASING ACCORDING TO THE AGE OF THE SUBJECTS. AT FOUR TESTS, DISPLACEMENT PLOTS, ANGLE-TIME-HISTORIES, ANGLE VELOCITY-TIME-HISTORIES OF THE CRANIAL-CERVICAL AND THE CERVICAL-THORACIC AXIS HAVE BEEN INVESTIGATED BY OPTICAL EVALUATIONOF HIGH-SPEED FILMS. A GREATER DISPLACEMENT OCCURRED AT A GREATER SEATING HEIGHT, HOWEVER, NOT AT A GREATER BODY WEIGHT. DURING THE FIRST 40 MILLISECONDS (MS) (30 KM/H IMPACT VELOCITY) RESPECTIVELY, 50 MS (40 KM/H IMPACT VELOCITY) A PURELY TRANSLATORY MOVEMENT OF THE CERVICAL SPINE TAKES PLACE. MAXIMUM FLEXION ANGLES HAVE BEEN ATTAINED AT 30 KM/H AFTER 130 MS TO 160 MS; AT 40 KM/H AT 110 MS. THE ANGLE VELOCITIES WERE HIGHER FOR MORE SERIOUS INJURED CERVICAL SPINES THAN THAT FOR SLIGHTLY INJURED ONES. VELOCITIES OF 98, 54, 26 AND23 RADIANS PER SECOND HAVE BEEN CALCULATED FOR THE ANGLE OF THE CERVICO-THORACIC TRANSITION.

R<DAT> 1975 R<AUT> SARRAILHE, S. R.; HEARN, N. D. R<COR> AUSTRALIAN DEFENCE SCIENTIFIC SERVICE, AERONAUTICAL RES. LABS., P.O. BOX 4331, M R<TTL> THE PERFORMANCE OF CONVENTIONAL AND ENERGY ABSORBING RESTRAINTS IN SIMULATED CRASH TESTS
<FIL>DOTI 02M28170 R<COL> 40P 7REFS R<REP> ARL/STRUC-359; ADA047532 R<AVA> CORPORATE AUTHOR
R<ISS> 78-09 R<ABS> DYNAMIC TESTS WERE PERFORMED, USING THE GENERAL MOTORS HOLDEN'S "HYGE" CRASH SIMULATOR, ON CONVENTIONAL LAP SASH SEATBELT RESTRAINTS AND OF ASSEMBLIES INCORPORATING ENERGY ABSORBERS IN THE SASH STRIP. INCLUDED IN THE TESTS WERE THREE RESTRAINT GEOMETRIES, RIGID AND CUSHIONED SEATS, AND ASSEMBLIES WITH THE STRAPS SLACK, TIGHT, AND PRELOADED. TESTS WITH A CONVENTIONAL SEAT BELT INDICATED THAT THE FORCES IN THE RESTRAINT COULD REACH THE TYPICAL DESIGN ULTIMATE LOADS FOR LIGHT AIRCRAFT, AT A CABIN PEAK DECELERATION OF ONLY 80 METERS PER SECOND PER SECOND, CORRESPONDING TO 8 G. ENERGY ABSORBERS IN THE RESTRAINT WOULD ALLOW THE SYSTEM TO WITHSTAND CABIN DECELERATIONS OF GREATER SEVERITY WITHOUT AN INCREASE IN THE RESTRAINT FORCES. INCORPORATION OF AN ENERGY ABSORBER INTO THE SASH STRIP OF A RESTRAINT SYSTEM REDUCED THE LOAD ON THAT STRAP TO HALF THE LOAD DEVELOPED IN A CONVENTIONAL CONFIGURATION. WHEN TESTED WITH THE SAME ACCELERATION PULSE, THREE-POINT AND FOUR-POINT BELT SYSTEMS ON SOFT OR RIGID SEATS DEVELOPED APPROXIMATELY THE SAME LOAD. HIGH LOADS WERE DEVELOPED BETWEEN THE DUMMY AND THE SEAT FRAME IN TESTS USING A CUSHIONED SEAT.

R<DAT> 1975 R<AUT> SERIZAWA, Y. R<COR> NISSAN MOTOR CO., INC., JAPAN R<TTL> EVALUATION OF SEAT BELT SYSTEM AND DUMMY CHARACTERISTICS
<FIL>DOTI 01M65980 R<CIT> HS-016 557, INTERNATIONAL TECHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES (5TH), WASHINGTON, D. C., 1975 P553-65 R<SUP> CONFERENCE HELD IN LONDON, 4-7 JUN 1974. R<COL> 21REFS R<AVA> IN HS-016 557 R<ISS> 75-10 R<ABS> THE EFFECTIVENESS OF SEAT BELTS IS RECOGNIZED, THE PROBLEMS INVOLVED IN THEIR USAGE ARE DISCUSSED, AND THE RESTRAINT CAPABILITY OF SEAT BELTS IS EXAMINED THROUGH EXPERIENCE WITH THE NISSAN ESV E-2 DEVELOPMENT. DETAILS ARE GIVEN ON: EFFECTIVENESS OF REDUCTION IN BELT SLACK; PROTECTION OF OCCUPANT FROM SECONDARY COLLISION WITH STEERING WHEEL AND COLUMN; FORCE LIMITING AND ENERGY ABSORBING BELT; POSITION OF ANCHOR POINTS FOR SEAT BELTS; KNEE PROTECTION; VEHICLE CRASHWORTHINESS; INFLUENCE OF DUMMY CHARACTERISTICS AND THEIR VARIATION INCLUDING NECK FLEXION AND HEAD MOTION, MATHEMATICAL SIMULATION MODELS; AND DIFFERENCES BETWEEN TEST AND ACTUAL COLLISION DATA.

R<DAT> 1974   R<AUT> ADOMEIT, D.   R<COR> INSTITUTE OF AUTOMOTIVE ENGINEERING, BERLIN TECHNICAL UNIV.   R<TTL> A FORCE LIMITING SYSTEM ON A THREE-POINT-BELT SYSTEM DEPENDING ON CRASH VELOCITY
<FIL>DOTI 01H56880   R<CIT> HS-015 670 (SAE-P-53), INTERNATIONAL CONFERENCE ON OCCUPANT PROTECTION (3RD) PROCEEDINGS, NEW YORK, 1974 P274-822   R<SUP> CONFERENCE HELD IN TROY, MICH., 10-12 JUL 1974, R<COL> 2REFS   R<REP> SAE-740582   R<AVA> IN HS-015 670   R<ISS> 75-05
R<ABS> THIS FORCE LIMITER PRODUCES A BELT FORCE SUCH THAT, AT THE MAXIMUM REQUESTED CRASH VELOCITY AND EACH LOWER ONE, THE MAXIMUM POSSIBLE RELATIVE FORWARD DISPLACEMENT BETWEEN PASSENGER AND VEHICLE WILL BE ALMOST USED. THE PASSENGER LOADS FROM THE BELT WILL BE REDUCED, AS WELL AS THE DECELERATIONS AFFECTING THE PASSENGER, AT A LOWER LEVEL THAN THE MAXIMUM REQUESTED CRASH VELOCITIES IN ACCIDENT STUDIES, AND INJURIES BY THE BELT WILL BE EFFECTIVELY REDUCED. THE PRINCIPLE OF THE FORCE LIMITER IS A HYDRAULIC THROTTLING MEMBER. DESCRIPTIONS ARE GIVEN OF THE MATHEMATICAL ANALOG-DIGITAL SIMULATION OF A SIMPLIFIED PASSENGER-VEHICLE MODEL, AND OF CONSTRUCTION OF A TEST UNIT OF A FORCE LIMITER TO APPROXIMATE THE THEORETICAL FINDINGS.

R<DAT> 1974   R<AUT> MACKAY, G. M.   R<TTL> SOME COST BENEFIT CONSIDERATIONS OF CAR OCCUPANT RESTRAINT SYSTEMS
<FIL>DOTI 01H67780   R<CIT> TECHNICAL ASPECTS OF ROAD SAFETY R<AVA> SEE PUBLICATION   R<ISS> 75-11   R<ABS> AN ANALYSIS IS GIVEN OF THE EFFECTIVENESS OF VARIOUS CAR OCCUPANT RESTRAINT SYSTEMS CURRENTLY BEING DEVELOPED IN EUROPE AND ELSEWHERE TOGETHER WITH ESTIMATES OF THEIR COSTS. THE ANALYSIS IS BASED ON THE SITUATION IN BRITAIN WHERE THREE POINT BELTS HAVE BEEN FITTED SINCE 1967, WITH RETROFIT TO 1965 CARS. THUS SOME 90% OF ALL CARS HAVE THREE POINT SYSTEMS FITTED TO THE FRONT SEATS. SEAT BELTS HAVE THEREFORE BEEN AVAILABLE FOR SOME YEARS. A CONSIDERABLE PROPAGANDA EFFORT TO ENCOURAGE THEIR USE HAS BEEN CONDUCTED BY THE BRITISH GOVERNMENT, AND SURVEYS SUGGEST USAGE RATES OF 15% IN TOWNS, 25% IN RURAL AREAS AND 50% ON HIGHWAYS. THIS SITUATION IS MARKEDLY DIFFERENT FROM MOST OTHER COUNTRIES IN EUROPE (EXCEPT SWEDEN) WHERE THE INSTALLATION OF BELTS IN SOME CASES IS NOT YET MANDITORY. A TABLE IS PRESENTED COMPARING USAGE (FRONT AND REAR), RELIABILITY OF OPERATION, EFFECTIVENESS IN REDUCING INJURY, PERFORMANCE FACTORS, FINANCIAL SAVINGS PER CAR LIFE, SYSTEM COST PER CAR, AND COST/BENEFIT RATIOS BETWEEN THE VARIOUS OCCUPANT RESTRAINT SYSTEMS. SYSTEMS COMPARED ARE: NORMAL THREE POINT BELT IN FRONT; NORMAL THREE POINT BELT FRONT AND REAR; NORMAL THREE POINT BELT ON ALL SEATS PLUS LOAD LIMITER; NORMAL THREE POINT BELT ON ALL SEATS PLUS PRELOADER; INERTIAL THREE POINT BELT ON ALL SEATS; INERTIAL THREE POINT BELT PLUS LIGHT AND BUZZER; INERTIAL THREE POINT BELT PLUS INTERLOCK; PASSIVE THREE POINT BELT IN FRONT AND ACTIVE THREE POINT BELT IN REAR; PASSIVE THREE POINT BELT FRONT AND REAR; AIRBAGS IN

R<DAT> 1974 R<AUT> SCHIMKAT, H. J. R<COR> VOLKSWAGENWERK A. G., WOLFSBURG (WEST GERMANY)(R<TTL> THEORETICAL AND EXPERIMENTAL INVESTIGATIONS ON THE CRASHWORTHINESS OF SMALL CARS
<FIL>DOTI 01H56790 R<CIT> HS-015 670 (SAE-P-53), INTERNATIONAL CONFERENCE ON OCCUPANT PROTECTION (3RD) PROCEEDINGS, NEW YORK, 1974 P131-400 R<SUP> CONFERENCE HELD IN TROY, MICH., 10-12 JUL 1974. R<COL> 2REFS R<REP> SAE-740573 R<AVA> IN HS-015 670 R<ISS> 75-05
R<ABS> THE PHILOSOPHY, DEVELOPMENT, AND OPTIMIZATION OF TWO VOLKSWAGEN EXPERIMENTAL SAFETY VEHICLES ARE PRESENTED: THE ESVW 1 AND THE ESVW 2. THE COLLISION SAFETY CRITERIA, VEHICLE DATA, OVERALL CONCEPT, CRASH STRUCTURE, AND OCCUPANT RESTRAINT SYSTEM OF THE ESVW 1 ARE DETAILED. THE ESVW 2 FULFILLS REQUIREMENTS FOR ACTIVE AND PASSIVE SAFETY FAR IN EXCESS OF THOSE FOR PRESENT DAY PRODUCTION VEHICLES. A FRONTAL BARRIER CRASH TEST AT 40 MPH WAS USED TO DEMONSTRATE ITS DEFORMATION CHARACTERISTICS. THE RESTRAINT SYSTEM USED FOR THE FRONT SEAT OCCUPANTS WAS A TWO-POINT BELT WITH KNEE BAR, AUTOMATIC RETRACTOR, FORCE LIMITERS AND PRELOADER. FOR THE REAR SEAT OCCUPANTS, THREE-POINT BELTS WITH AUTOMATIC RETRACTORS, FORCE LIMITERS AND PRELOADERS WERE USED. THEORETICAL CONSIDERATIONS OF STRUCTURAL COMPONENTS WERE WORKED OUT WITH THE AID OF THE FINITE ELEMENT METHOD SUPPLEMENTED BY STATIC PRESSURE TESTS. THE DESIGN WAS CONFIRMED IN A DYNAMIC TEST WITH THREE OCCUPANTS AND MEASURING INSTRUMENTS (1100 KP). AT A MEASURED MEAN PASSENGER CELL DECELERATION OF 24 G, THE VALUES FOR THE HEAD INJURY CRITERION AND SEVERITY INDEX FOR THE CHEST WERE CONSIDERABLY BELOW THE TOLERABLE VALUE OF 1000 AND THE FEMUR LOADS WERE BELOW THE TOLERABLE VALUE OF 771 KP. AT ITS PRESENT STAGE OF DEVELOPMENT, THE ESVW 2 IS ABOUT 15% HEAVIER THAN THE PRODUCTION MODEL FROM WHICH IT WAS DEVELOPED, AND WOULD COST ABOUT 30% MORE. THESE FACTORS WOULD APPEAR UNACCEPTABLE FROM A COST-BENEFIT POINT OF VIEW. HOWEVER, WITH ESVW 2, VOLKSWAGENWERK HAS ENDEAVORED TO SHOW WHAT POSSIBILITIES EXIST FOR THE FULFILLMENT OF EXTREME SAFETY REQUIREMENTS WITH SMALL CARS.

R<DAT> 1972 R<AUT> CACCIABUE, A. R<COR> MOTOR VEHICLES SAFETY DESIGN OFFICE R<TTL> FRONTAL CRASH--INFLUENCE OF THE DECELERATION MODE (AT THE SEAT BELTS ANCHORAGE POINTS) ON SEVERITY INDICES
<FIL>DOTI 01H35350 R<AVA> IN HS-820 217, INTERNATIONAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLES (3RD) REPORT, WASHINGTON, D. C., 1972 P2-141--2-146 R<ISS> 73-23 R<ABS> THE INFLUENCES OF SEAT BELT CHARACTERISTICS AND DECELERATION MODES OF SEAT BELT ANCHORAGES ON DUMMY MOTION WERE STUDIED. A SIMPLE SCHEME LIMITED TO THE CENTRAL PART OF THE BODY, WHICH IS ASSUMED TO BE A CONCENTRATED MASS, CONNECTED TO THE VEHICLE BY MEANS OF A BELT WITH GIVEN DEFORMATION CHARACTERISTICS, WAS USED. THE LAW OF MOTION OF THE BELT ANCHORAGES WAS ALSO ASSUMED KNOWN. THE TRADITIONAL, ELASTIC TYPE BELTS EXAMINED GAVE SIMILAR SEVERITY INDEXES FOR THE MASS AND FOR THE ANCHORAGES. SOME IMPROVEMENT COULD BE OBTAINED WITH CRITICAL DAMPING BELTS. MUCH BETTER RESULTS COULD BE GIVEN BY CONSTANT FORCE BELTS. THE FILTERING SYSTEM, CONSISTING OF THE BODY MASS AND THE ELASTIC RIGIDITY OF THE BELT, RENDERED THE MASS RATHER UNSENSITIVE TO THE SHAPE OF THE DECELERATION DIAGRAM ATTRIBUTED TO THE ANCHORAGES. MORE PARTICULARLY, ONLY THE FIRST HARMONIC OF THE FOURIER SERIES DEVELOPMENT OF THE EXCITATION DIAGRAM CAN MAKE A NOTICEABLE DIFFERENCE TO THE SEVERITY INDEX OF THE MASS RESTRAINED BY THE BELT.

R<DAT> 1972 R<AUT> FIALA, E. R<COR> VOLKSWAGENWERK A.G., WOLFSBURG (WEST GERMANY) R<TTL> THE VOLKSWAGEN ESV
<FIL>DOTI 01H35400 R<AVA> IN HS-820 217, INTERNATIONAL TEHNICAL CONFERENCE ON EXPERIMENTAL SAFETY VEHICLE (3RD) REPORT, WASHINGTON, D. C., 1972 P2-198--2-212 R<ISS> 73-24 R<ABS> VOLKWAGEN'S EXPERIMENTAL SAFETY VEHICLE (ESV) IS A FOUR DOOR SEDAN FOR FOUR OCCUPANTS. THE GENERAL DESIGN OF THE ESV AND SPECIAL SAFETY CHARACTERISTICS ARE DESCRIBED. THE PASSIVE RESTRAINT SYSTEM FOR ALL PASSENGERS CONSISTS OF A SHOULDER BELT AND A KNEE BELT WITH THE PRELOADING MECHANISM LOCATED IN THE CENTRAL TUNNEL. EACH HAS A FORCE LIMITER. TESTS CONDUCTED ON THE ESV ARE MENTIONED AND SOME RESULTS OF IMPACT TESTS ARE PRESENTED. THE VOLKSWAGEN ESV IS A PRACTICAL AUTOMOBILE WHICH MEETS, OR EXCEEDS, THE ESV SPECIFICATIONS. HOWEVER, THE TOTAL ADDITIONAL OWNERSHIP COST OF THIS ESV IS ESTIMATED TO BE $5,100. BENEFIT COST STUDIES INDICATE THAT MUCH OF THE EXCESSIVE ESV COSTS COME FROM THE HIGH-SPEED CRASH REQUIREMENTS OF THE SPECIFICATIONS. BECAUSE REAL-WORLD CRASHES AT THESE HIGH SPEEDS ARE RARE, THE GAIN IN OCCUPANT SAFETY IS LIMITED DESPITE THE HIGH COST OF SUCH PROTECTION.

R<DAT> 1972 R<AUT> WILLUMEIT, H. P. R<COR> VOLKSWAGENWERK A. G. (WEST GERMANY) R<TTL> PASSIVE PRELOADED ENERGY=ABSORBING SEAT BELT SYSTEM. IMPROVED BELT SYSTEMS
<FIL>DOTI 01H17730 R<SUP> PRESENTED AT THE 2ND INTERNATIONAL CONFERENCE ON PASSIVE RESTRAINTS, DETROIT, 22=25 MAY 1972. R<COL> 9P R<REP> SAE=720433 R<AVA> SAE R<ISS> 72=21 R<ABS> SAFETY BELT RESTRAINT SYSTEMS CAN BE IMPROVED BY USING SEMI=PASSIVE AND FULL PASSIVE DEVICES WHICH LEAD TO A HIGH AND INCREASING UTILIZATION WITHOUT A CONSIDERABLE DECREASE IN THE USER'S COMFORT. IMPROVEMENTS FOR INCREASED INJURY PROTECTION ARE GIVEN BY INTRODUCING BELT FORCE LIMITERS AND DEVICES WHICH ELIMINATE THE BELT SLACK AT THE MOMENT OF CRASH BEGINNING, AND, FURTHERMORE, GIVE A CERTAIN PRELOAD TO THE BELTS, ENABLING THE PASSENGER TO TAKE PART IN THE VEHICLE DECELERATION ALMOST FROM CRASH ONSET. RESULTS OF SLED TESTS COMPLETE THE DESCRIPTION. A FINAL COMPARISON WITH THE AIRBAG SHOWS THE HIGHER PROTECTION POSSIBILITIES OF BELT RESTRAINT SYSTEMS AGAINST INJURIES.

R<DAT> 1970 R<AUT> CAMPBELL, H.E. R<TTL> A PROPOSAL FOR PERSONNEL RESTRAINTS IN THE AUTOMOBILE
<FIL>DOTI 01H07900 R<CIT> JOURNAL OF TRAUMA V10 N7 P611=5 (JUL 1970) R<AVA> SEE PUBLICATION R<ISS> 72=07 R<ABS> THE CRASHING MOTORIST MUST ENTER THE DECELERATIVE SITUATION IN THE ERECT POSTURE FOR TWO REASONS: THERE IS NO ROOM IN THE AUTOMOBILE FOR NONINJURIOUS JACKKNIFING; IN EVEN MODERATE JACKKNIFING, RUPTURE OF THE DIAPHRAGM BY THE HEAVY ABDOMINAL ORGANS AND RUPTURE OF THE HEART OR GREAT VESSELS BY BLOOD=COLUMN DISPLACEMENT, MAY OCCUR. THE CURRENT TWO=INCH SHOULDER STRAP REPRESENTS A GREAT ADVANCE, BUT IN HEAVY CRASHES IT IMPOSES A HIGH=ENERGY X2= LOAD OVER A TOO=LIMITED AREA. IN EXPERIMENTAL CRASHES UPON PREGNANT BABOONS, THE INVERTED=Y CONFIGURATIO PROVED THE LEAST TRAUMATIC. IT IS SUGGESTED THAT THIS CONFIGURATION BE SUPPLEMENTED BY: A) A FOUR=INCH STRAP ACROSS THE CHEST CONNECTING THE TWO SHOULDER STRAPS; OR B) A TEN=INCH CONNECTION EXTENDING FROM THE SUPRASTERNAL NOTCH TO BELOW THE XIPHOID, EMPLOYING A RUGGED HEAVY=DUTY ZIPPER; OR C) AN EXTENTION OF THIS STRUCTURE OVERLAPPING THE SEAT BELT.

R<DAT> 1968 R<COR> U.S. STEEL R<TTL> SCHOOL BUS SEATING FOR PASSENGER PROTECTION AND SAFETY. A DESIGN STUDY PRESENTED BY UNITED STATES STEEL
<FIL>DOTI 02H01140 R<COL> 42P 13REFS R<AVA> REFERENCE COPY ONLY R<ISS> 77-05 R<ABS> A NEW SCHOOL BUS SEAT DESIGN IS OFFERED WHICH WOULD BE EFFICIENT AND, CONSTRUCTED OF THE RIGHT STEEL, WOULD CONTRIBUTE MAXIMUM EFFECTIVENESS AND SAFETY. SEATBACK HEIGHTS FOR ALL SCHOOL BUSES SHOULD BE AT LEAST 28 INCHES HIGH. SEATBACK STRENGTH SHOULD INCLUDE ALLOWANCE FOR PASSENGERS THROWN FORWARD AGAINST THE BACKREST AND SHOULD BE SUFFICIENT TO WITHSTAND, WITHOUT FAILURE, A 30-G DECELERATION FORWARD, HEAD-ON, AND A 20-G ACCELERATION FORWARD, REAR-END. SEAT ANCHORAGES AND SEAT CUSHION FASTENERS SHOULD NOT FAIL FROM FORWARD DECELERATIONS UNDER 30 G'S. SEATS SHOULD NOT BE PROVIDED WITH RIGID PROTRUDING STRUCTURES SUCH AS HANDGRIPS, HANDRAILS, AND SIMILAR INJURY-PRODUCING APPURTENANCES. THIN PADDING COVERING RIGID TUBULAR STRUCTURES SUCH AS THE TOP OF THE SEATBACKS AND ARMRESTS CANNOT COUNTERACT THE PROBLEMS OF AN INADEQUATE DESIGN. A HIGH-STRENGTH, HIGH-BACKED SAFETY SEAT REPRESENTS THE MOST IMPORTANT SINGLE CONTRIBUTION TO SCHOOL BUS PASSENGER COLLISION SAFETY, THE NEXT IMPORTANT BEING THE THREE-POINT BELT. DESIGN OF THE TOP EDGE OF THE BUS SEATS WAS CONSIDERED AS SIMILAR TO THE PASSENGER-SIDE ZONE OF AN ENERGY-ABSORBING AUTOMOTIVE INSTRUMENT PANEL. SEATING SHOULD PROVIDE EXPANDED SEAT CAPACITIES, SUFFICIENT LEG ROOM, AND AISLE-SIDE HIP RETAINERS THAT WOULD ALSO SUPPORT THE SEATBACK. CONSIDERATIONS OF LOAD TRANSFER CONNECTIONS LED TO THE FOLLOWING DECISIONS. BECAUSE OF LIMITED SPACING, THE SEAT SHOULD BE NONCOLLAPSING WITH A DIAGONAL LEG PLACED IN THE OPPOSITE DIRECTION, PERMITTING BUCKLING FAILURE UNDER IMPACT. INDIVIDUAL LEGS FOR EACH PAIR OF SEAT BELT ENDS SHOULD BE INCORPORATED DESPITE THE CLUTTER RESULTING FROM THREE SETS OF LEGS AND A WALL CONNECTION. THE MOST LIKELY OF SEVERAL IMPROVED FLOOR CONNECTIONS WAS RECOMMENDED. THE PROTOTYPE USES STEEL SHEET TO PROVIDE AN INTEGRAL CONTOURED BACK AND SEAT, MEETING DIMENSIONS OF CHILDREN FROM 13-17 YEARS. INDIVIDUAL LEGS SUPPORT THE AISLE SIDE AND EACH SEAT BELT ANCHOR POINT. THE OTHER SIDE OF THE SEAT AND THE LAST SEAT BELT END ARE ANCHORED TO THE SIDE STRUCTURE OF THE BUS. THE COMPUTED TUBE SECTION FOR THE SEAT LEGS IS A ONE-INCH SQUARE TUBE FORMED FROM 16-GAGE STEEL SHEET HAVING A 36,000-PSI MINIMUM YIELD STRENGTH. THE SEAT PAN, EXCLUSIVE OF THE ENERGY-ABSORBING TOP RAIL, IS ALSO MADE OF 16-GAGE MILD STEEL. THE FEET OF THE AISLE-SIDE SEAT SUPPORTS ANGLE IN TO PROVIDE AISLE WALKING ROOM. THE SEAT HAS AN INTEGRATED IMPACT-ENERGY-ABSORBING CUSHION FIVE INCHES IN DIAMETER AND AN AISLE-SIDE HIP RETAINER WITH A ROLLED ONE-INCH DIAMETER. THE SEAT IS CONNECTED TO THE FLOOR THROUGH SUPPORTING FLOOR MEMBERS CAPABLE OF WITHSTANDING THE IMPOSED LOADS, AND IS PADDED FRONT, TOP, AND BACK WITH ONE-INCH THICK CELLULAR VINYL RUBBERIZED HAIR PAD AND COVERED WITH VINYL. STATIC TESTS WERE CONDUCTED FOR SEAT DISPLACEMENT AND DIRECTION OF STRAIN USING TWO BELTED 50 PERCENTILE MALES, 165 LBS, EACH DECELERATING EVENLY AT THE RATE OF 30 G'S. STATIC TESTING SHOWED THE SEAT CAPABLE OF MEETING 30-G DECELERATION HEAD-ON AND 20-G ACCELERATION

REAR-END IN THE FORWARD DIRECTION. PRELIMINARY DYNAMIC TESTING RESULTS PERFORMED WITH THE TEST VEHICLE TRAVELING AT 35 MPH AT IMPACT SHOWED THE PROTOTYPE WITHSTOOD BARRIER IMPACT SUCCESSFULLY. THE SEATBACK PANEL DID DEFORM UNDER IMPACT, ALLOWING POCKETING OF THE KNEES FOR PASSENGERS BEHIND. ONE MODIFICATION IS PRESENTED USING A CONVENTIONAL SPRING SEAT WHICH WOULD REQUIRE A MINIMUM NUMBER OF MODIFICATIONS. IT HAS AN IMPACT-ABSORBING SEATBACK, AISLE-SIDE RETENTION DEVICE, SEAT BELT MANIFOLD THAT WITHSTANDS 15,000 POUNDS, RESISTED BY THE SUPPORTING LEG STRUCTURE AND THE FLOOR.

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